Nucleon clustering and alpha decay of nuclei

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- Thank NSFC, RIKEN-MOST, STDFM (澳门科技发展基金）等资助

Outline

- **Introduction**
- **Density-dependent cluster model (DDCM) and generalized DDCM for alpha-decay half-lives**
- **Multi-channel cluster model (MCCM) : solve coupled-channel Schrödinger--equations of quasi-bound states for alpha-decay half-lives and branching ratios**
- **New Geiger-Nuttall law of alpha decay**
- **Summary**

Congratulate Arima sensei 88 birthday
祝贺有马先生88岁生日快乐

- I saw Prof. Arima many times (RIKEN,1996…)
- Around 2002, I got a call from the Office of Foreign Affairs in Nanjing University that Prof. Arima planed to visit Beijing. We invited him to visit Nanjing University also and he was given an honoury professor of Nanjing Univrsity. I was in charge of this (his talk, the procedure for the honoury professor).
- I met Arima Sensei in Shanghai Jiao Tong University (around 2011). He told me he walks everyday even if it rains or snows.

I (Zhongzhou REN) and Bo Zhou (my student) congratulations:

- We write an article to congratulate Arima sensei 88 birthday in Frontiers of Physics （2018）.

- We have good collaborations with Japanese physicists: Horiuchi-san, Tohsaki-san, Yamada-san, Funaki-san.
- We are also collaborating with Hiyama-san, En'yo-san on researches.

Clustering: China-Japan-France-Germany
PRL 110, 262501 (2013): nonlocalized

PRL **110,** 262501 (2013) PHYSICAL REVIEW LETTERS week ending 28 JUNE 2013

Nonlocalized Clustering: A New Concept in Nuclear Cluster Structure Physics

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(Received 5 April 2013; revised manuscript received 17 May 2013; published 24 June 2013)

We investigate the $\alpha + {}^{16}\mathrm{O}$ cluster structure in the inversion-doublet band ($K^\pi = 0_1^\pm$) states of $^{20}\mathrm{Ne}$ with an angular-momentum-projected version of the Tohsaki-Horiuchi-Schuck-Röpke (THSR) wave function, which was successful "in its original form" for the description of, e.g., the famous Hoyle state. In contrast with the traditional view on clusters as localized objects, especially in inversion doublets, we find that these *single* THSR wave functions, which are based on the concept of nonlocalized clustering, can well describe the $K^\pi = 0_1^-$ band and the $K^\pi = 0_1^+$ band. For instance, they have 99.98% and 99.87% squared overlaps for 1^- and 3^- states (99.29%, 98.79%, and 97.75% for 0^+, 2^+, and 4^+ states), respectively, with the corresponding exact solution of the $\alpha + {}^{16}\mathrm{O}$ resonating group method. These astounding results shed a completely new light on the physics of low energy nuclear cluster states in nuclei: The clusters are nonlocalized and move around in the whole nuclear volume, only avoiding mutual overlap due to the Pauli blocking effect.

We develop cluster model (THSR) from N=Z=Even nuclei (previous researches) to N=Z+1 nuclei (^{9}Be…, Lyu, Ren,..Horiuchi,…PRC 2015). Schematic Fig.:

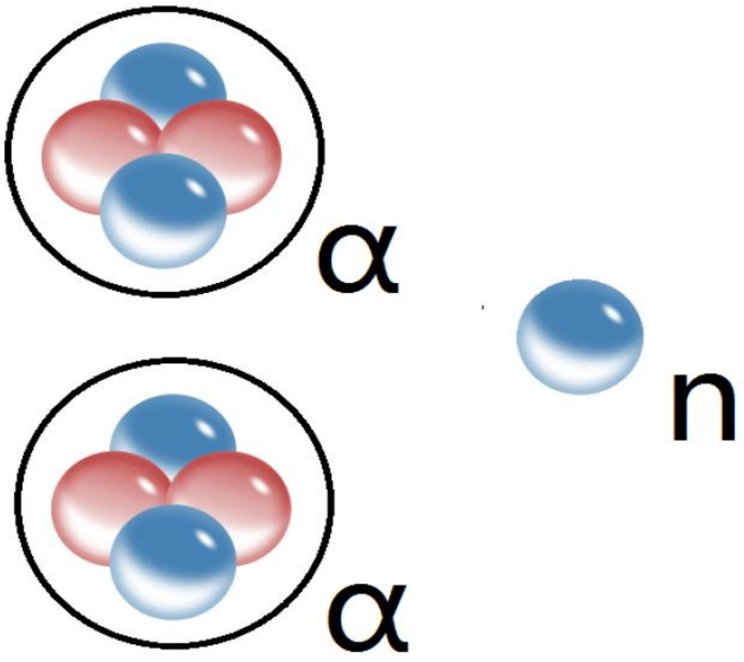
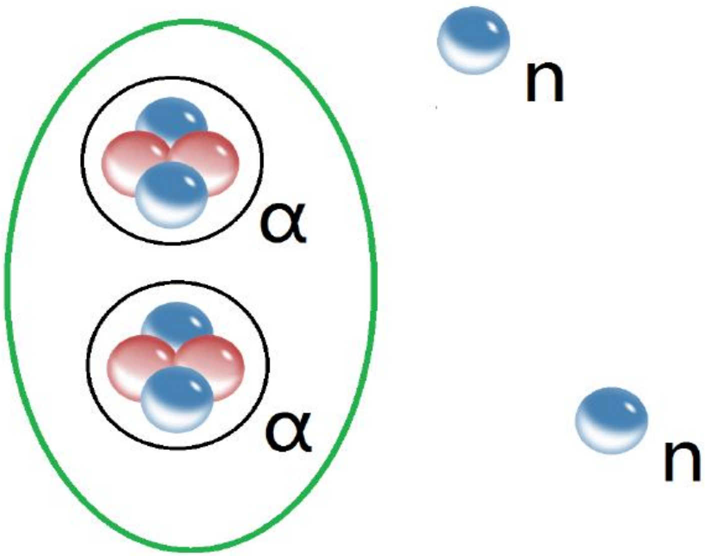


Figure: Cluster structure of ^{9}Be.

We develop cluster model (THSR) from N=Z=Even nuclei (previous researches) to N=Z+2 or N=Z=odd nuclei (^{10}Be, ^{10}B…, Lyu, Ren, Horiuchi,…Zhao…, PRC2016, PRC2018).

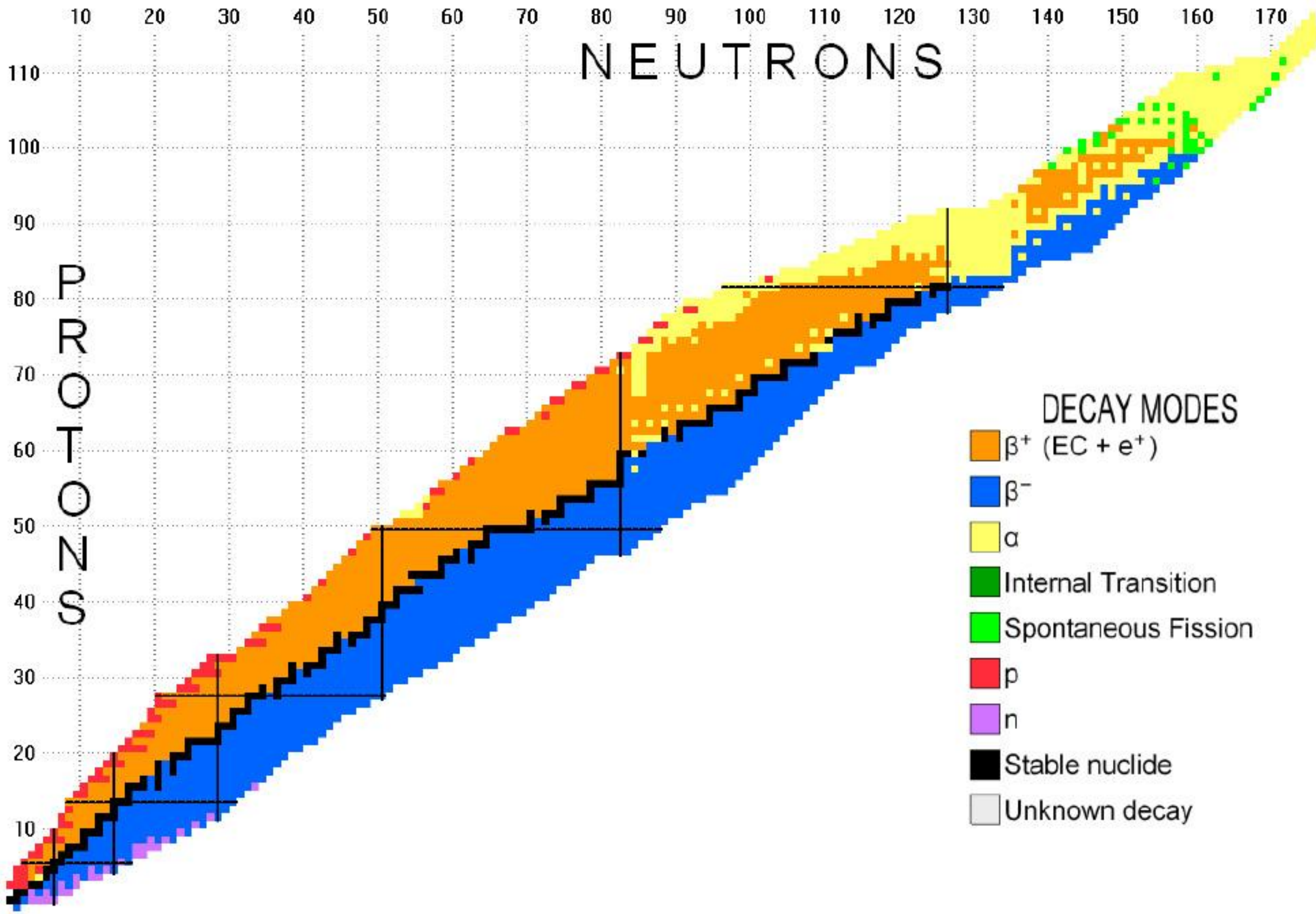


Schematic Fig.: **Cluster structure of ^{10}Be**

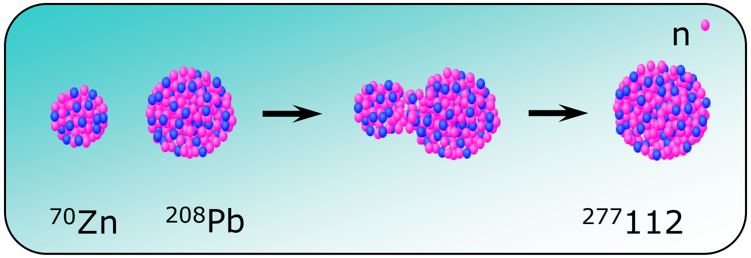
Now move to alpha decay of nuclei: importance of alpha decay

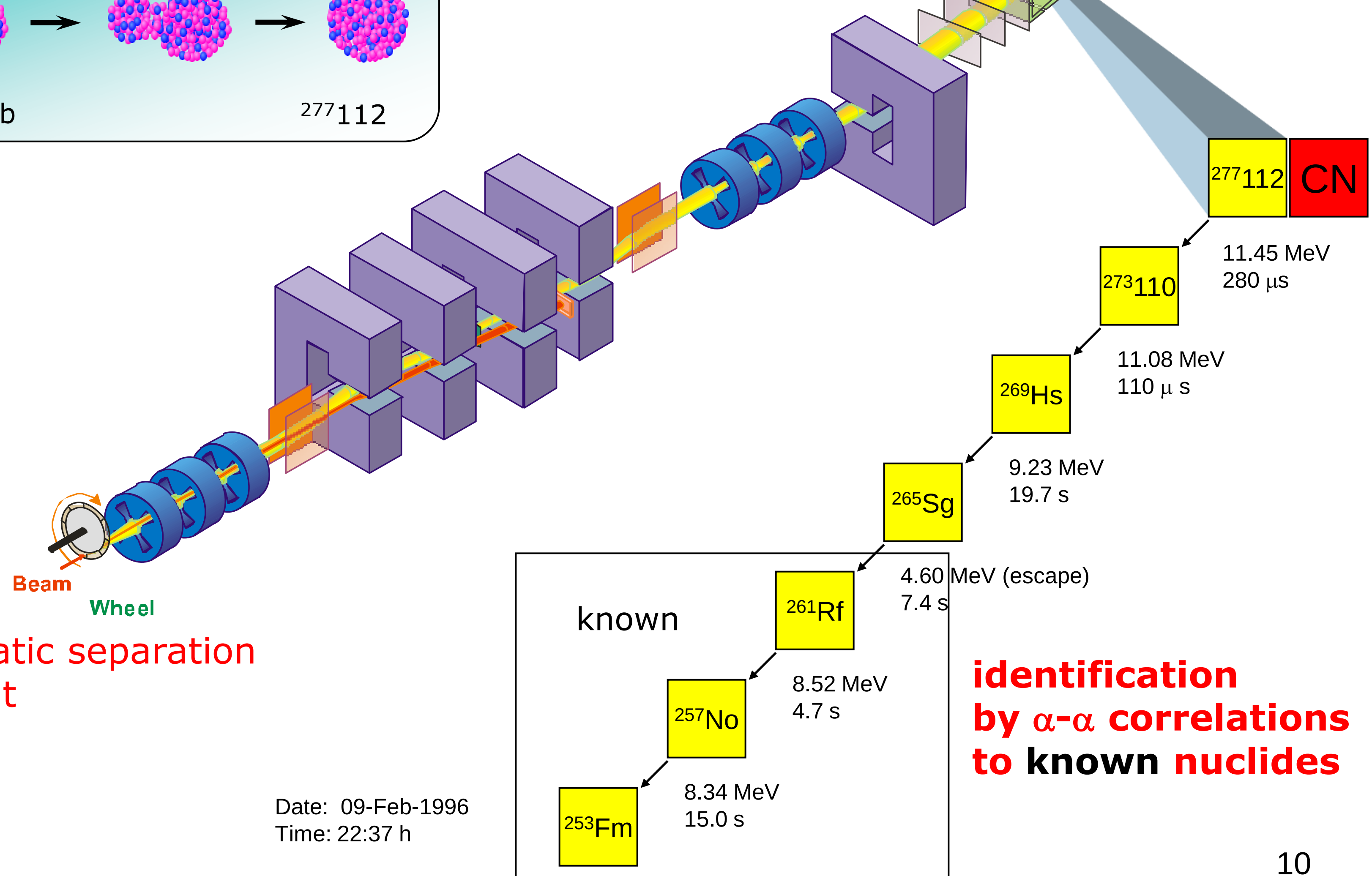
- Origin of nuclear physics 1896: Becquerel
- Identify new elements (Po and Ra) by stronger radioactivity: Curies. Z=105-118…
- Identify the core of atom (nucleus): Rutherford
- Validity of quantum mechanics for nuclear Physics: Gamow in 1928

There are more than 400 nuclei that exhibit the alpha-decay phenomenon (yellow one).



Synthesis of Z=112 SHE at SHIP





kinematic separation
in flight

Date: 09-Feb-1996
Time: 22:37 h

identification
by α-α correlations
to known nuclides

Z=113,115,117,118 identified by alpha decay

- Z=113: Nihonium, Nh. (produced in RIKEN).
- Z=115: Moscovium, Mc. (produced in Dubna).
- Z=117: Tennessine, Ts. (produced in Dubna).
- Z=118: Oganesson; Og. (produced in Dubna).

Oganessian et al, PRC72, 034611 (2005)

PHYSICAL REVIEW C **72**, 034611 (2005)

Synthesis of elements 115 and 113 in the reaction $^{243}Am + ^{48}Ca$

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(Received 21 March 2005; published 29 September 2005)

The results of two experiments designed to synthesize element 115 isotopes in the $^{243}Am + ^{48}Ca$ reaction are presented. Two new elements with atomic numbers 113 and 115 were observed for the first time. With 248-MeV ^{48}Ca projectiles, we observed three similar decay chains consisting of five consecutive α decays, all detected

Predictions of SHF and RMF compare well with MM results [12,13]

[13] Z. Ren *et al.*, Phys. Rev. C **67**, 064302 (2003).

In our experiments, α-decay properties proposed by the MM nuclear model [6,7] were used for setting the initial experimental parameters. One should note that the predictions of other models within the Skyrme-Hartree-Fock-Bogoliubov (SHFB) and the relativistic mean-field (RMF) approaches compare well with the MM results (see, e.g., [12,13]). Unfortunately, calculations of the probability of spontaneous fission and electron capture for odd nuclei are rather scarce.

Oganessian et al, PRC72 2005

V. DISCUSSION

The experimental α-decay energies Q_α^{exp} of the synthesized isotopes and previously known odd-Z nuclei with $Z \geqslant 103$ are plotted in Fig. 9(a). The Q_α^{exp} of even-Z nuclei, including those produced in our experiments [1,2,20], are plotted in Fig. 9(b) for comparison. The α-decay energies attributed to the isotopes of Mt and Bh coincide well with theoretical values [7], also plotted in the figures. The same can be seen for the last nuclei in the decay chain ^{275}Hs $\rightarrow$ ^{271}Sg $\rightarrow$ ^{267}Rf.

The trend of the $Q_\alpha(N)$ systematics predicted by the MM model [6,7] and confirmed by experimental data for odd-Z isotopes of Mt and Bh along with even-Z isotopes of Ds can

SHF [12, 49-51] and RMF [13, 52-57] compare well with the experimental results

considerable increase in T_α for the new heavier isotopes Db

[54] Z. Ren, Phys. Rev. C **65**, 051304(R) (2002).

[55] S. Das and G. Gangopadhyay, J. Phys. G **30**, 957 (2004).

[56] Z. Ren *et al.*, Phys. Rev. C **67**, 064302 (2003).

For the isotopes ^{279,280}Rg and ^{283,284}113 the difference between theoretical and experimental Q_α values is 0.6–0.9 MeV. Some part of this energy can be accounted for by γ-ray emission from excited levels populated during α decay. For the even-Z nuclei as well, the agreement between theory and experiment becomes somewhat worse as one moves from the deformed nuclei in the vicinity of neutron shells $N = 152$ and $N = 162$ to the more neutron-rich nuclides with $N \geqslant 169$. In this region, experimentally measured values of Q_α are less than the values calculated from the model by $\leqslant 0.5$ MeV. Although the predicted Q_α values for the heaviest nuclei observed in our experiments are systematically larger than the experimental data as a whole, the trends of the predictions are in good agreement for the 23 nuclides with $Z = 106$–118 and $N = 165$–177, especially considering that the theoretical predictions of the MM model match the experimental data over a broad previously unexplored region of nuclides.

One should note that the predictions of other models for even-Z and odd-Z nuclei within the Skyrme-Hartree-Fock-Bogoliubov [12,49–51] and the relativistic mean-field [13,52–57] methods also compare well with the experimental results. These models predict the same spherical neutron shell at $N = 184$, but different proton shells, $Z = 114$ (MM) and $Z = 120$, 124, or 126 (SHFB, RMF), yet all describe the experimental data equally well. Such insensitivity with respect

15. Ren, Z. Shape coexistence in even-even superheavy nuclei. Phys. Rev. C65, 051304 (2002)

Cited: shape coexistence, Ref. [15]

Nature, 433 (2005) 705

review article

Shape coexistence and triaxiality in the superheavy nuclei

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* Deceased

Superheavy nuclei represent the limit of nuclear mass and charge; they inhabit the remote corner of the nuclear landscape, whose extent is unknown. The discovery of new elements with atomic numbers $Z \geq 110$ has brought much excitement to the atomic and nuclear physics communities. The existence of such heavy nuclei hangs on a subtle balance between the attractive nuclear force and the disruptive Coulomb repulsion between protons that favours fission. Here we model the interplay between these forces using self-consistent energy density functional theory; our approach accounts for spontaneous breaking of spherical symmetry through the nuclear Jahn–Teller effect. We predict that the long-lived superheavy elements can exist in a variety of shapes, including spherical, axial and triaxial configurations. In some cases, we anticipate the existence of metastable states and shape isomers that can affect decay properties and hence nuclear half-lives.

New isotope in China: 265Bh (Z=107)

Eur. Phys. J. A **20**, 385–387 (2004)

THE EUROPEAN PHYSICAL JOURNAL A

Letter

New isotope ^{265}Bh

Z.G. Gan[1,a], J.S. Guo[1], X.L. Wu[1], Z. Qin[1], H.M. Fan[1], X.G. Lei[1], H.Y. Liu[1], B. Guo[1], H.G. Xu[1], R.F. Chen[1], C.F. Dong[1], F.M. Zhang[1], H.L. Wang[1], C.Y. Xie[1], Z.Q. Feng[1], Y. Zhen[1], L.T. Song[1], P. Luo[1], H.S. Xu[1], X.H. Zhou[1], G.M. Jin[1], and Zhongzhou Ren[2]

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Data of 265Bh agree with Ren et al [12,13]

. The derived Q_α from the measured α energy for ^{265}Bh was 9.38 MeV, which was in agreement with the expected Q_α value by Zhongzhou Ren *et al.* [12, 13]. The experimental half-life of ^{265}Bh also agrees with the calculations [13] $T_{1/2} = 2.6$

Ren et al., PRC 70 (2004) 034304, Density-Dependent Cluster Model (DDCM): new model ^{4}He, ^{14}C decay

PHYSICAL REVIEW C **70**, 034304 (2004)

New perspective on complex cluster radioactivity of heavy nuclei

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(Received 15 June 2004; published 14 September 2004)

Experimental data of complex cluster radioactivity (^{14}C–^{34}Si) are systematically analyzed and investigated with different models. The half-lives of cluster radioactivity are well reproduced by a new formula between half-lives and decay energies and by a microscopic density-dependent cluster model with the renormalized M3Y nucleon-nucleon interaction. The formula can be considered as a natural extension of both the Geiger-Nuttall law and the Viola-Seaborg formula from simple α decay to complex cluster radioactivity where different kinds of clusters are emitted. It is useful for experimentalists to analyze the data of cluster radioactivity. A new linear relationship between the decay energy of cluster radioactivity and the number of α particles in the cluster is found where the increase of decay energy for an extra α particle is between 15 and 17 MeV. The possible physics behind this new linear relationship is discussed.

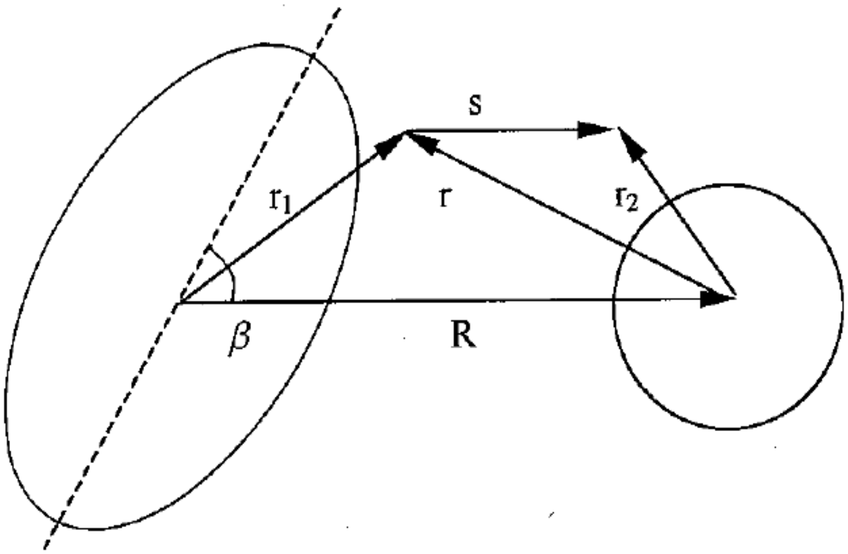
Density-Dependent Cluster Model

- DDCM: model of alpha and cluster decay:
- 1) N-N effective potential: from Reid potential
- 2) Double folding with density: alpha+nucleus
- 3) low density behavior--exchange included
- 4) agree well with experimental half-lives

- Z Ren, C Xu, Z Wang, PRC 70: 034304 (2004)
- C Xu, Z Ren, NPA 753: 174 ,NPA 760: 303 (2005)
- C Xu, Z Ren, PRC 73: 041301(R) (2006)…
- D. Ni, Z. Ren, PRC , (2009), (2010), GDDCM…..

Schematic Fig.: double folding potential or Woods-Saxon potential

We consider a spherical alpha-particle interacts with a deformed core nucleus which has an axially symmetric nuclear shape.



The decay process is described by the tunneling of the alpha particle through a deformed potential barrier, which is approximated by an axially deformed potential.

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **73**, 041301(R) (2006)

New deformed model of α-decay half-lives with a microscopic potential

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The α-decay half-lives of deformed nuclei are investigated in a new version of the density-dependent cluster model. By the multipole expansion method, the deformation- and orientation-dependent double-folding potential is derived to calculate the α-decay width through a deformed Coulomb barrier. We perform systematic calculations for the ground-state α transitions of even-even nuclei with $Z = 52-104$. The theoretical results are in good agreement with the experimental data. This is, to our knowledge, the first deformed calculation of α-decay half-lives within the framework of microscopic double-folding potentials. A unified description of α-decay half-lives of both spherical and deformed nuclei is obtained by the microscopic potentials.

alpha decay and quantum mechanics

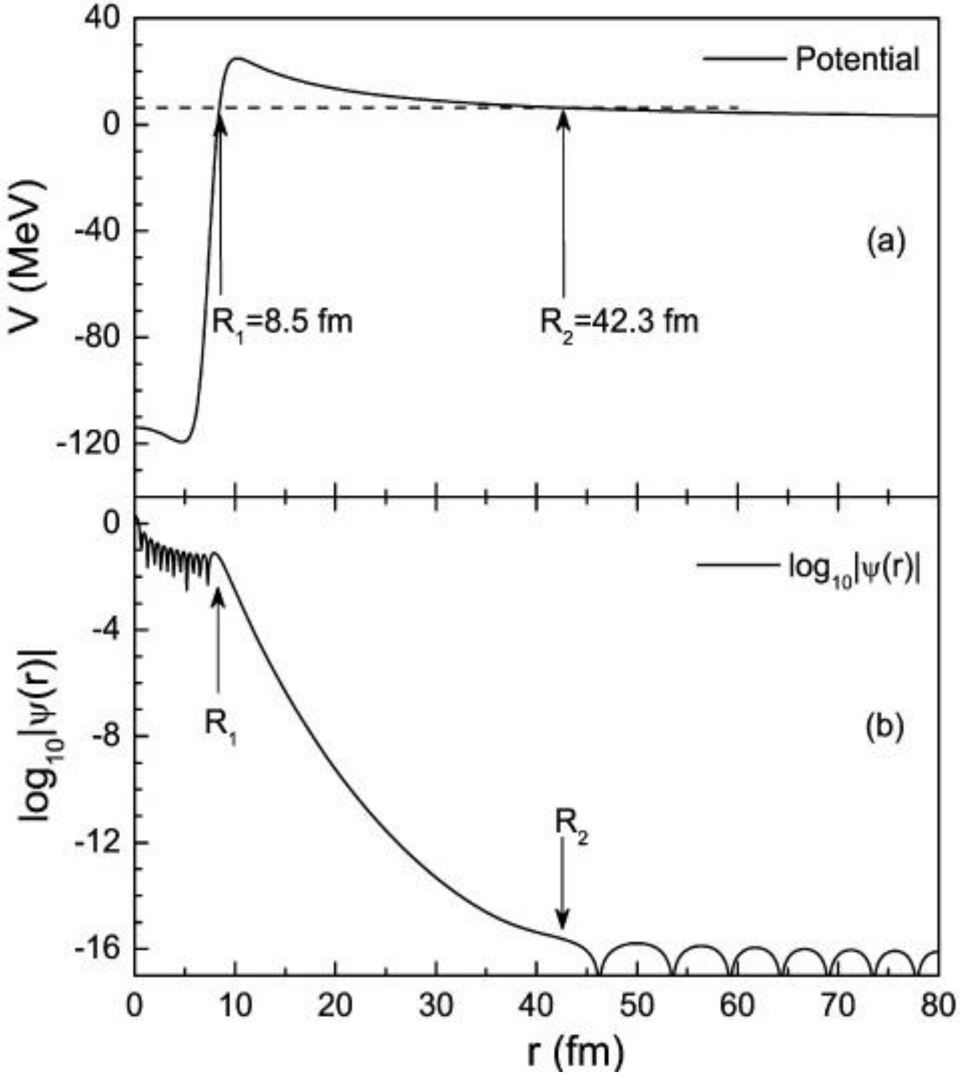
- **Quantum mechanics: originated from atomic physics. Two kinds of states in textbook: bound, scattering**

  1928，Gamow: quantum tunnel
- **Unstable nuclei (^{238}U): finite lifetime: Quasi-Bound State (QBS)**

- **Our DDCM: WKB, Bohr-Sommerfeld quantization, semi-classical approximation**
- **alpha-decay : quantum effect. To solve Schroedinger-eq. for QBS**

- **Generalized Density-Dependent Cluster Model**
- **Multi-Channel Cluster Model (MCCM)**

QBS: wave function of Woods-Saxon potential, tail

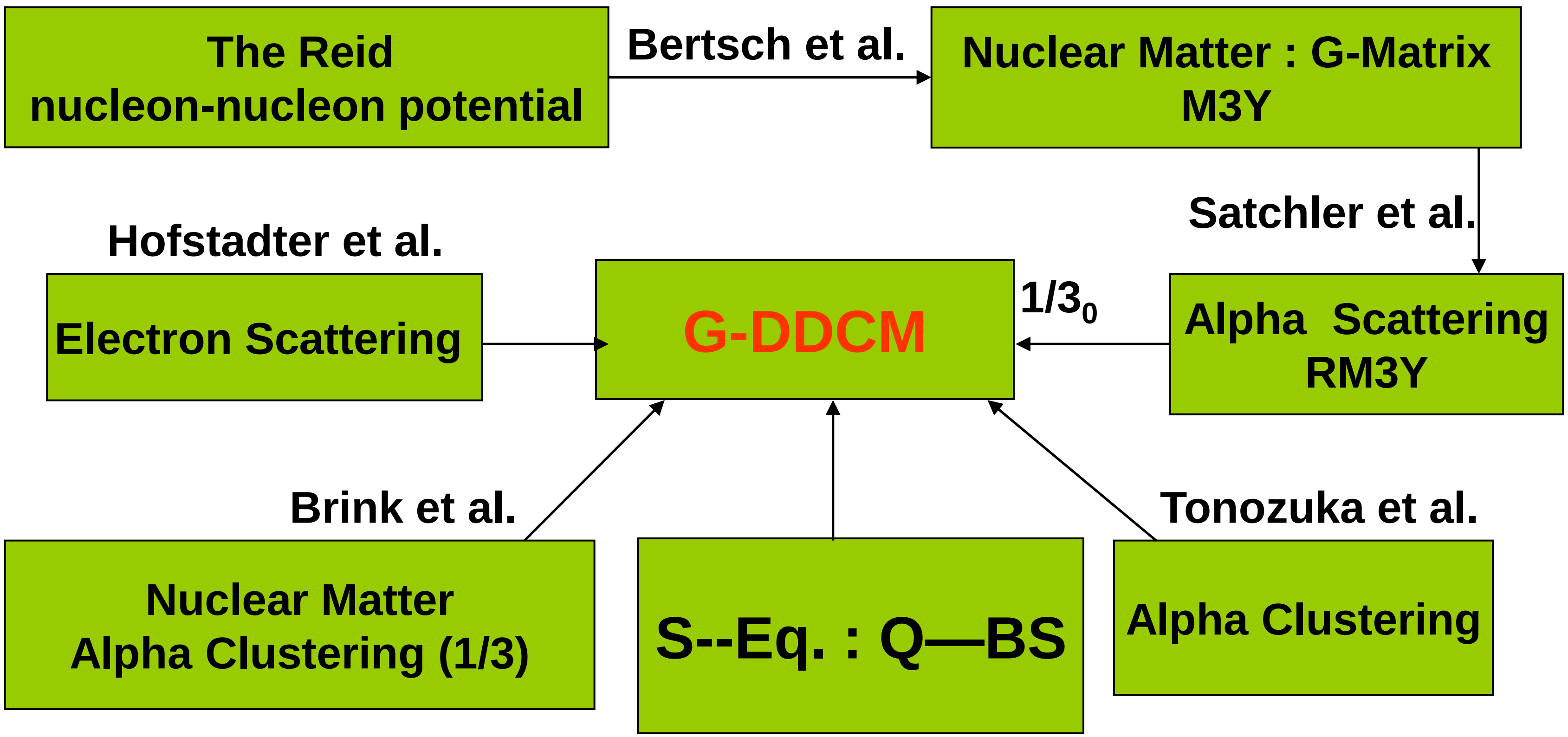


Woods-Saxon shape nuclear potentials

$$V_N(r) = \frac{V_0}{1 + \exp\left(\frac{r - r_0 A^{1/3}}{a}\right)}$$

V_0 is determined by the characteristic of the alpha-cluster quasibound state.

Generalized Density-Dependent Cluster Model



Generalized Density-Dependent Cluster Model
PRC 80 014314 (2009)

PHYSICAL REVIEW C **80**, 014314 (2009)

Exotic α decays around the $N = 126$ magic shell

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(Received 26 May 2009; published 20 July 2009)

We investigate the α-decay half-lives of the exotic $N = 125, 126, 127$ isotones by the generalized density-dependent cluster model (GDDCM) in combination with the microscopic two-level model. The decay widths are calculated using the overlap integral of the quasibound state wave function, the scattering state wave function, and the difference of potentials, instead of using the simple semiclassical WKB method along with the Bohr-Sommerfeld quantization condition. The α-preformation factors are evaluated by the Z-dependent formula based on the two-level model, where the closed-shell effect is included. The calculated half-lives of α transitions to both ground states and excited states are found to be in good agreement with the experimental data.

DOI: 10.1103/PhysRevC.80.014314 PACS number(s): 23.60.+e, 21.10.Tg, 21.60.Gx, 27.80.+w

Multi-Channel Cluster Model (MCCM): alpha-decay of deformed nuclei 2010---

PHYSICAL REVIEW C **81**, 064318 (2010)

New approach for α-decay calculations of deformed nuclei

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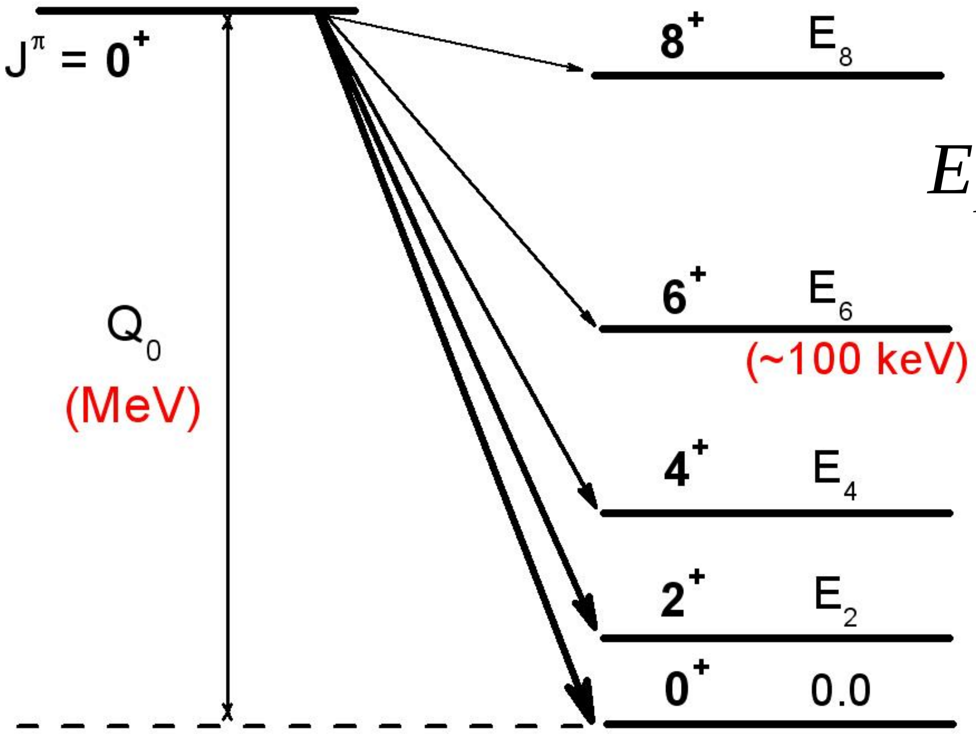
(Received 31 March 2010; published 22 June 2010)

We present a new theoretical approach to evaluate α-decay properties of deformed nuclei, namely the multichannel cluster model (MCCM). The deformed α-nucleus potential is taken into full account, and the coupled-channel Schrödinger equation with outgoing wave boundary conditions is employed for quasibound states. Systematic calculations are carried out for well-deformed even-even nuclei with $Z \geqslant 98$ and isospin dependence of nuclear potentials is included in the calculations. Fine structure observed in α decay is well described by the four-channel microscopic calculation, which is performed for the first time in α-decay studies. The good agreement between experiment and theory is achieved for both total α-decay half-lives and branching ratios to the ground-state rotational band of daughter nuclei. Predictions on the branching ratios to high-spin daughter states are presented for superheavy nuclei, which may be important to interpret future observations.

Schematic diagram of the alpha decay of well-deformed even-even nuclei



$$E_I = \kappa I(I+1)$$

Key points (five channels)

- **The deformed potential *V* is expanded in spherical multipoles to order 12.**
- **The dynamics of the core is included in evaluating the interaction matrix elements.**
- **The Boltzmann distribution hypothesis is proposed for daughter states to simulate the internal effect of nuclear states on alpha-cluster formation.**
- **A more realistic description of alpha decay has been achieved.**

The total wave function of the system

$$\Psi_{JM} = \phi(\alpha) r^{-1} \sum_{I\ell} u^{J}_{n\ell I}(r) \left[Y_{\ell}(\hat{r}) \otimes \Phi_{I} \right]_{JM}$$

The set of coupled equations for the radial components

$$\left[-\frac{\hbar^2}{2\mu} \left(\frac{d^2}{dr^2} - \frac{\ell_\alpha(\ell_\alpha + 1)}{r^2} \right) - \left(Q_0 - E_I \right) \right] u_\alpha(r)$$

$$+ \sum_{\alpha'} V_{\alpha\alpha'}(r) u_{\alpha'}(r) = 0, \quad [\alpha \equiv (n\ell I)]$$

The multipole expansion of the interaction potential

$$V(r) = \sum_{\lambda=0}^{\lambda_{\max}} \upsilon_\lambda(r) \left(\Omega_\lambda \otimes Y_\lambda \right)_{00}$$

The coupling potential between channels α and α’

$$V_{\alpha,\alpha'}(r) = \sum_{\lambda} \upsilon_{\lambda}(r) \frac{(-1)^{\lambda}}{\sqrt{4\pi}} \sqrt{(2\ell'+1)(2I+1)(2\lambda+1)}$$
$$\times \langle \ell'\lambda 00 | \ell 0\rangle W(\ell'\lambda JI;\ell I') \langle \Phi_I \| \Omega_\lambda \| \Phi_{I'} \rangle$$

For rotational nuclei, the reduced matrix elements are assumed as

$$\langle \Phi_I \| \Omega_\lambda \| \Phi_{I'} \rangle = \sqrt{\frac{(2\lambda+1)(2I'+1)}{4\pi(2I+1)}} \langle I'\lambda K0 | IK \rangle$$

Coupled-channel wave functions

(1) The potential depth V_0 is adjusted to make all channels reproduce the experimental Q_{J_d} values.

(2) The Wildermuth condition $G = 2n + \ell = \sum_{i=1}^{4} g_i$

(3) Boundary conditions for different channels

$$u_{n\ell j}(r \to 0) = 0;$$

$$u_{n\ell j}(r \to \infty) = N_{\ell j}\left[G_\ell(k_{J_d} r) + iF_\ell(k_{J_d} r)\right].$$

Alpha-cluster formation

- A constant preformation factor is used for ground state of all even-even nuclei (P_α =0.36).

  This value is not only consistent with the experimental data of open-shell nuclei but also supported by the microscopic calculation.

- The hypothesis of Boltzmann distributions ρ(E_l) is proposed for daughter states, as Einstein did for molecules with a set of discrete states.

  This implies that there is a gradual decline in the P_α factor with increasing daughter spins.

The total decay width representing the tunneling through the deformed barrier

$$\Gamma = \sum_{\{\ell I\}} P_\alpha \rho(E_I) \Gamma_{\ell I}$$

The partial decay width corresponding to the decay into a core state *I*

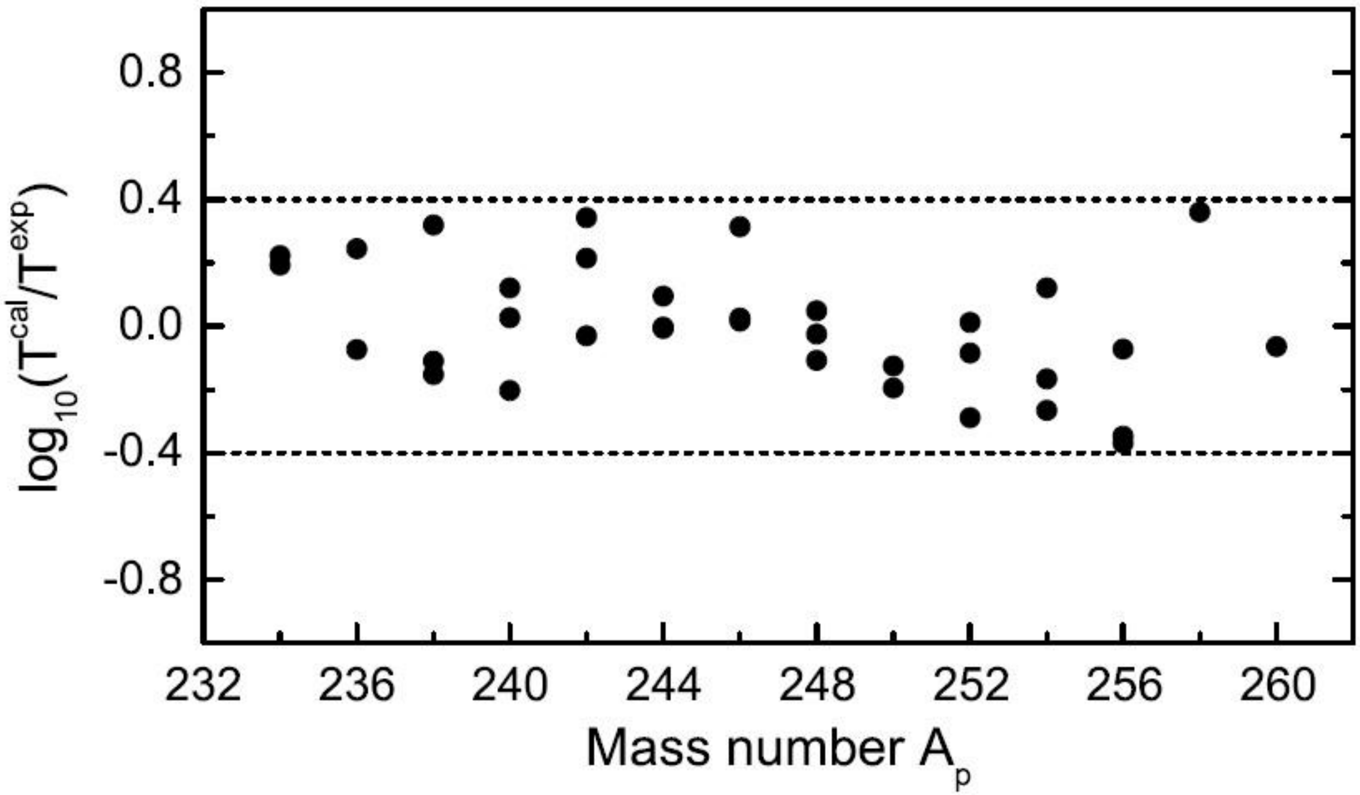
$$\Gamma_{\ell I} = \frac{\hbar^2 k_I}{\mu} \frac{|u_{n\ell I}(R)|^2}{G_\ell(k_I R)^2 + F_\ell(k_I R)^2}$$

The alpha-decay half-lives and branching ratios (BR) are expressed as

$$T_{1/2} = \hbar \ln 2 / \Gamma$$

$$\mathrm{BR} = P_\alpha \rho(E_I) \Gamma_{\ell I} / \Gamma \times 100\%$$

The comparison of experimental alpha-decay half-lives with theoretical ones for well-deformed emitters



$$\sigma = \sqrt{\sum_{i=1}^{35} \frac{1}{34} \left[\log_{10} \left(T^{i}_{\rm expt} / T^{i}_{\rm calc} \right) \right]^2} = 0.19$$

Calculated results for two isotopes of Cf

^{250}Cf	*Exp.* (%)	*Cal.* (%)
8^+	---	5.8×10^{-5}
6^+	~0.01	0.010
4^+	0.3	0.66
2^+	15.0	22.73
0^+	84.7	76.60
$T_{1/2}$(s)	4.13×10^8	3.09×10^8

^{252}Cf	*Exp.* (%)	*Cal.* (%)
8^+	6.0×10^{-5}	7.9×10^{-5}
6^+	0.002	0.0089
4^+	0.24	0.95
2^+	15.7	19.76
0^+	84.2	79.29
$T_{1/2}$(s)	8.61×10^7	8.87×10^7

Calculated results for two isotopes of Fm

^{252}Fm

Level	Exp. (%)	Cal. (%)
8^+	---	3.8×10^{-4}
6^+	0.023	0.022
4^+	0.97	1.45
2^+	15.0	21.60
0^+	84.0	76.93
$T_{1/2}$(s)	9.14×10^4	4.70×10^4

^{254}Fm

Level	Exp. (%)	Cal. (%)
8^+	---	4.8×10^{-4}
6^+	0.0066	0.0126
4^+	0.82	1.41
2^+	14.2	20.30
0^+	85.0	78.28
$T_{1/2}$(s)	1.17×10^4	7.95×10^3

Multichannel calculations for fine structure in odd-A nuclei（maximum 25 channels）

PHYSICAL REVIEW C **86**, 054608 (2012)

Systematic calculation of fine structure in the α decay of heavy odd-mass nuclei

Dongdong Ni[1,*] and Zhongzhou Ren[1,2,3,†]
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(Received 28 October 2012; published 28 November 2012)

Multichannel calculations for fine structure in odd-odd nuclei（maximum 25 channels）

PHYSICAL REVIEW C **87**, 027602 (2013)

Theoretical description of fine structure in the α decay of heavy odd-odd nuclei

Dongdong Ni[1,*] and Zhongzhou Ren[1,2,3,†]
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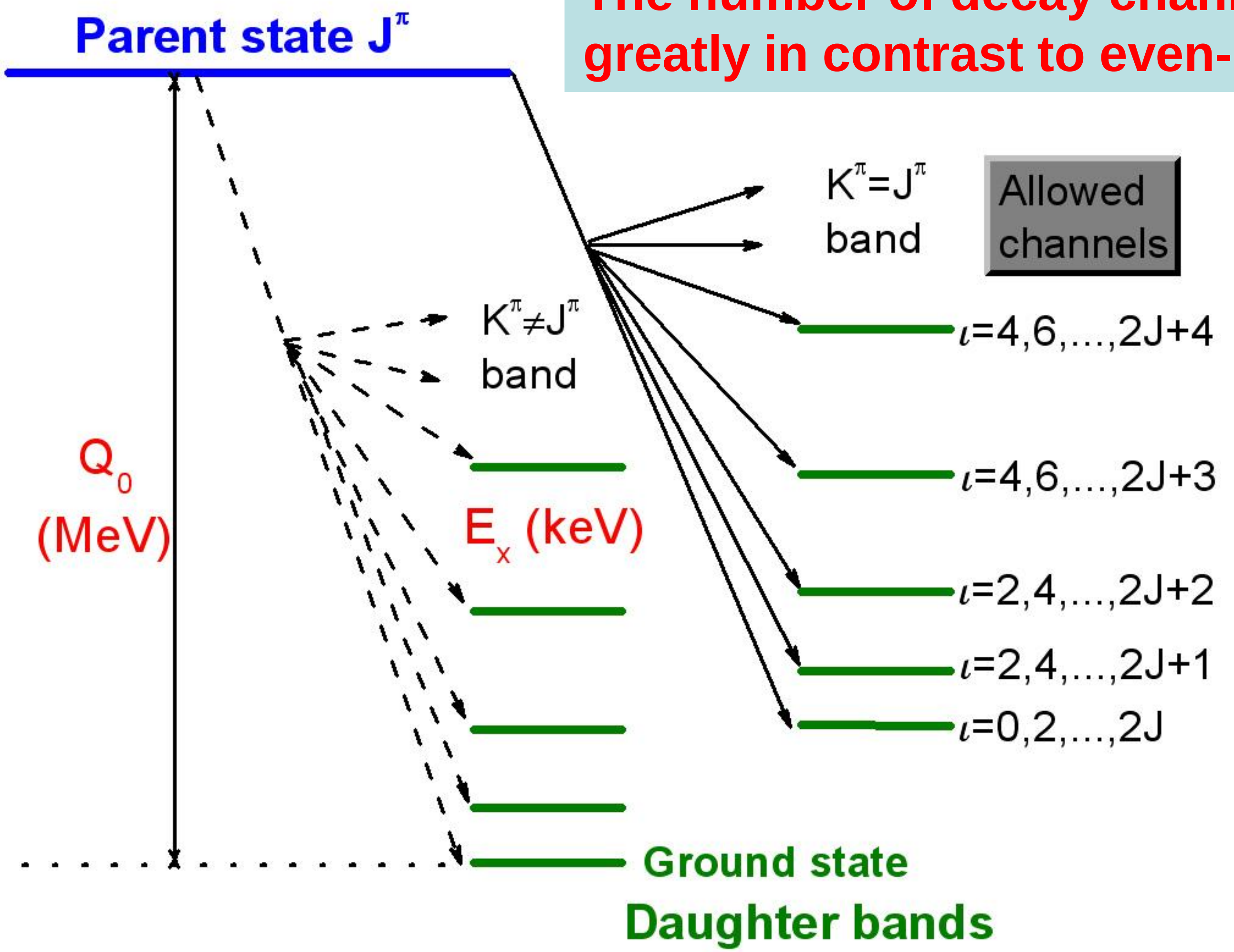
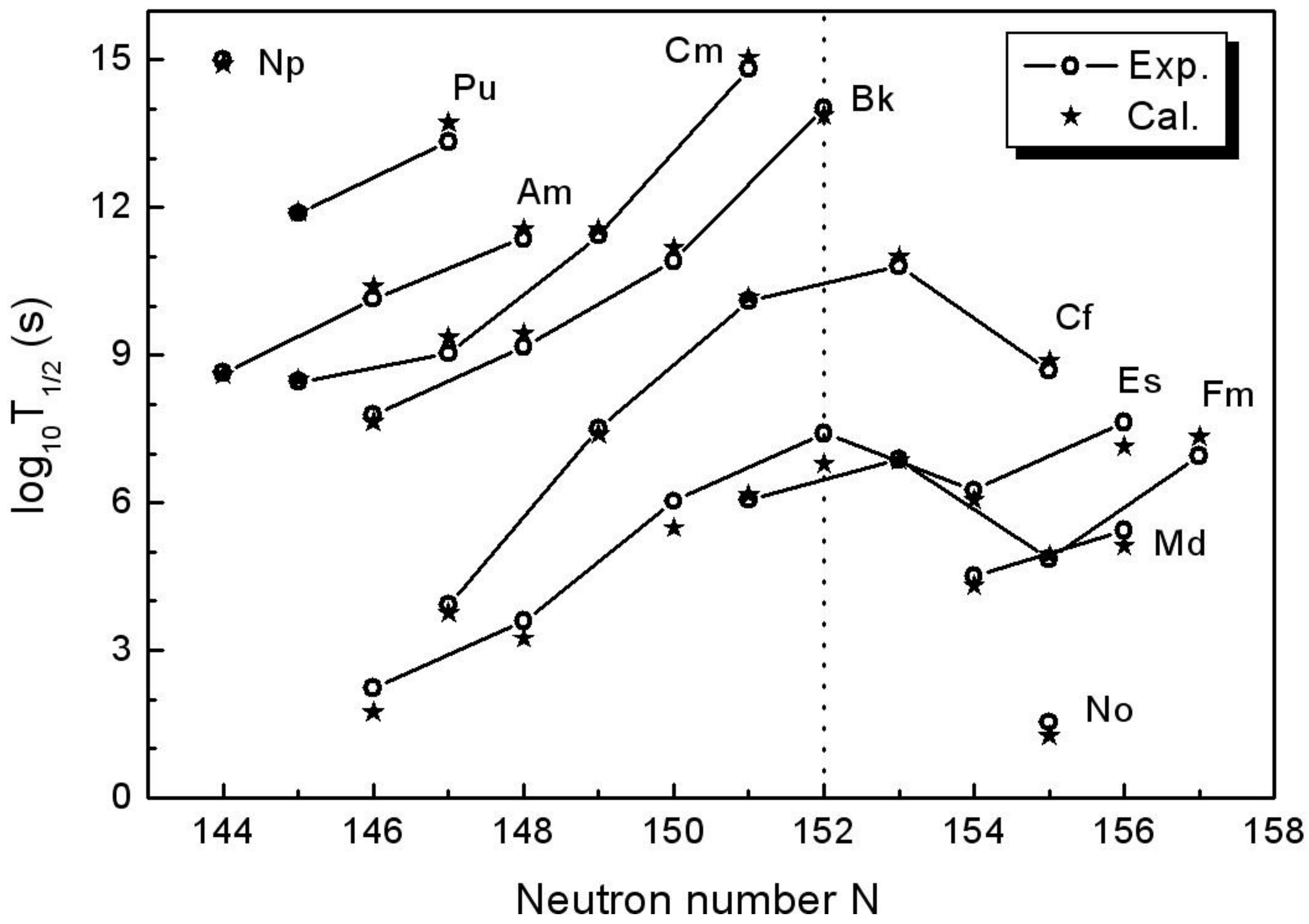
(Received 1 February 2013; published 28 February 2013)

Diagram of the alpha decay of deformed odd-mass nuclei (to favored rotational bands)

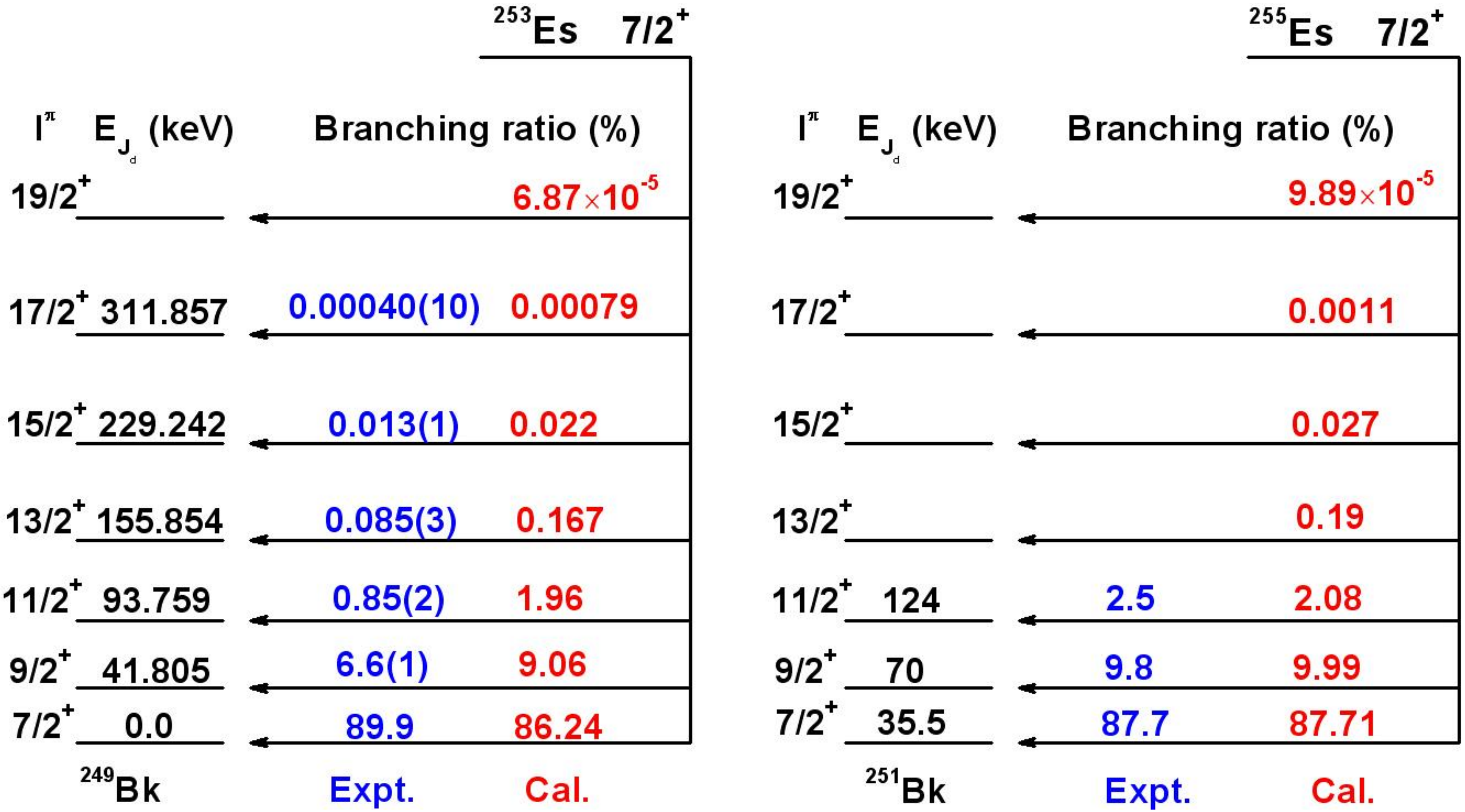
The number of decay channels increases greatly in contrast to even-even nuclei



Comparison of calculated alpha-decay half-lives with the experimental data (within a factor of about 1.9)



24 decay channels considered for odd-A Es isotopes
(Ni and Ren, PRC 86, 054608, 2012)



Calculated results for odd-odd Am isotopes

(23 and 25 decay channels considered)

^{240}Am (3^-) → ^{236}Np

I^π	E_{J_d} (keV)	Branching ratio (%) Expt	Calc$_1$ (MCCM)	Calc$_2$ (WKB)
(9^-)			4.39×10^{-5}	0.0011
(8^-)			1.89×10^{-4}	0.0043
(7^-)			0.0061	0.16
(6^-)			0.069	0.49
(5^-)	324	1.23(10)	1.83	6.48
(4^-)	273	12.0(4)	13.53	15.54
(3^-)	231	86.8(10)	84.56	77.31

^{242}Am* 5^- → ^{238}Np

I^π	E_{J_d} (keV)	Branching ratio (%) Expt	Calc$_1$ (MCCM)	Calc$_2$ (WKB)
11^-			5.02×10^{-7}	1.59×10^{-5}
10^-			2.57×10^{-5}	1.91×10^{-4}
9^-			5.38×10^{-4}	0.017
8^-			0.0055	0.11
7^-	484	0.25(7)	0.15	2.86
6^-	407.59	5.6(2)	2.07	11.12
5^-	342.439	89.0(7)	92.62	85.89

New G-N law: PRC 85 (2012) 044608

Effects of the quantum numbers of quasibound states are included into the formula.

PHYSICAL REVIEW C **85**, 044608 (2012)

New Geiger-Nuttall law for α decay of heavy nuclei

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(Received 12 February 2012; published 10 April 2012)

Recent α-decay data of heavy nuclei are collected and systematic analysis shows that there is a sudden change between the logarithm of decay half-life and the reciprocal of the square root of decay energy across the $N = 126$ shell closure. In order to reproduce this sudden change, the new Geiger-Nuttall law is proposed where the effects of the quantum numbers of α-core relative motion are naturally embedded in the law. The remedy achieved by a very simple parametrization of these effects is remarkable. By adding terms to the Geiger-Nuttall law, the parameters in the formula of decay half-lives need not be changed, except for some odd nuclei. This is an important development to the original Geiger-Nuttall law, which is valid for the ground-state transitions of even-even nuclei with $N \geqslant 128$. The law is generalized to the favored and hindered transitions of the $N \leqslant 128$ nuclei and of high-spin isomers. The results of this article point to the simplicity of the underlying mechanism of the decay.

PRC2014：new isotope ^{205}Ac

PHYSICAL REVIEW C **89**, 014308 (2014)

α decay of the new neutron-deficient isotope ^{205}Ac

Z. Y. Zhang (张志远),[1] Z. G. Gan (甘再国),[1,*] L. Ma (马龙),[1,2,3] L. Yu (郁琳),[1,2] H. B. Yang (杨华彬),[1,2,3] T. H. Huang (黄天衡),[1] G. S. Li (李广顺),[1] Y. L. Tian (田玉林),[1] Y. S. Wang (王永生),[1] X. X. Xu (徐新星),[4] X. L. Wu (吴晓蕾),[1] M. H. Huang (黄明辉),[1,5] C. Luo (罗成),[1] Z. Z. Ren (任中洲),[6,7] S. G. Zhou (周善贵),[7,8] X. H. Zhou (周小红),[1] H. S. Xu (徐瑚珊),[1] and G. Q. Xiao (肖国青)[1]

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[6]*Department of Physics, Nanjing University, Nanjing 210093, China*

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(Received 1 December 2013; published 13 January 2014)

The new neutron-deficient isotope ^{205}Ac was synthesized in the complete-fusion reaction ^{169}Tm(^{40}Ca, $4n$)^{205}Ac. The evaporation residues were separated in-flight by the gas-filled recoil separator SHANS in Lanzhou and subsequently identified by the α-α position and time correlation method. The α-decay energy and half-life of ^{205}Ac were determined to be 7.935(30) MeV and 20^{+97}_{-9} ms, respectively. Previously reported decay properties of the ground state in ^{206}Ac were confirmed.

PRC2014：new isotope ^{205}Ac

In Refs. [16,17], a new version of the Geiger-Nuttall law including the quantum numbers of α-core relative motion was proposed, which reproduces the α-decay half-lives of heavy nuclei with $N \leqslant 126$ very well. In Fig. 3(b), a calculation using this law is carried out for the favored α-decay transitions, and the results are compared with experimental values. The calculated 15-ms half-life of ^{205}Ac is in good agreement with the value measured in the present experiment.

The calculated half-life (15 ms) with new Geiger-Nuttall law [16,17] agrees well with the measured data (20^{+97}_{-9} ms).

[16] Yuejiao Ren and Zhongzhou Ren, Phys. Rev. C **85**, 044608 (2012).

[17] Yuejiao Ren and Zhongzhou Ren, Nucl. Sci. Tech. **24**, 050518 (2013), http://www.j.sinap.ac.cn/nst/EN/Y2013/V24/I5/50518.

New isotope ^{216}U: identified by alpha decay chain:
Ma, Zhang, Gan,..,Ren,Zhou..PRC 91 (2015) 051302

PHYSICAL REVIEW C **91**, 051302(R) (2015) **RAPID COMMUNICATIONS**

α-decay properties of the new isotope ^{216}U

L. Ma (马龙),[1,2,3] Z. Y. Zhang (张志远),[1] Z. G. Gan (甘再国),[1,*] H. B. Yang (杨华彬),[1,2,3] L. Yu (郁琳),[1,2] J. Jiang (姜舰),[1,2] J. G. Wang (王建国),[1] Y. L. Tian (田玉林),[1] Y. S. Wang (王永生),[1] S. Guo (郭松),[1] B. Ding (丁兵),[1] Z. Z. Ren (任中洲),[4,5] S. G. Zhou (周善贵),[5,6] X. H. Zhou (周小红),[1] H. S. Xu (徐瑚珊),[1] and G. Q. Xiao (肖国青)[1]

The new neutron-deficient isotope ^{216}U was produced in the complete-fusion reaction ^{180}W(^{40}Ar, $4n$)^{216}U. The evaporation residues were separated from the primary beam in flight by the gas-filled recoil separator Spectrometer for Heavy Atoms and Nuclear Structure. The activities have been identified by the α-α position and time correlation measurements. Two α-decaying states with $E_\alpha = 8384(30)$ keV, $T_{1/2} = 4.72^{+4.72}_{-1.57}$ ms for the ground state and $E_\alpha = 10582(30)$ keV, $T_{1/2} = 0.74^{+1.34}_{-0.29}$ ms for an isomeric state were identified in ^{216}U.

PHYSICAL REVIEW C **87**, 024310 (2013)

Nuclear charge radii of heavy and superheavy nuclei from the experimental α-decay energies and half-lives

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(Received 10 December 2012; revised manuscript received 18 January 2013; published 13 February 2013)

The radius of a nucleus is one of the important quantities in nuclear physics. Although there are many researches on ground-state properties of superheavy nuclei, researches on charge radii of superheavy nuclei are rare. In this article, nuclear root-mean-square (rms) charge radii of heavy and superheavy nuclei are extracted from the experimental α-decay data. α-decay calculations are performed within the generalized density-dependent cluster model, where α-decay half-lives are evaluated using quasibound state wave functions. The charge distribution of daughter nuclei is determined in the double-folding model to reproduce the experimental α-decay half-lives. The rms charge radius is then calculated using the resulting charge distribution. In addition, a simple formula is also

First result on charge radii of superheavy nuclei by decay data

The two different methods show good agreement with the experimental data for even-even nuclei, and the deduced results are consistent with other theoretical models. Moreover, nuclear radii of heavy and superheavy nuclei with $Z = 98$–116 are extracted from the α-decay data, for which α decay is a unique tool to probe nuclear sizes at present. This is the first result on nuclear charge radii of superheavy nuclei based on the experimental α-decay data.

PRC 89 (2014) 024318: Nuclear charge radii of superheavy odd-mass and odd-odd nuclei from α-decay data

PHYSICAL REVIEW C **89**, 024318 (2014)

Tentative probe into the nuclear charge radii of superheavy odd-mass and odd-odd nuclei

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(Received 12 December 2013; revised manuscript received 20 January 2014; published 26 February 2014)

The root-mean-square (rms) nuclear charge radii of superheavy odd-A and odd-odd nuclei are tentatively pursued by the deduction of experimental α decay data. The framework of calculating α decay half-lives is constructed via the combination of the improved two-potential approach with the density-dependent cluster model. In this procedure, the charge distribution of daughter nuclei is determined to exactly reproduce the measured α decay half-lives. Next, the rms charge radius of daughter nuclei is obtained by using the corresponding charge distribution. For comparison, the previously proposed formula of our group is employed to estimate the rms charge radii as well. Besides the reasonable agreement between the extracted nuclear charge radii and the available experimental values, the nuclear radii of heaviest odd-A and odd-odd nuclei are extracted from the α decay energies and half-lives. This can be considered as an effective attempt in terms of the nuclear size in the superheavy mass region.

Microscopic calculation of α preformation factor ^{212}Po (PRC 2016, Xu, Ren,…Horiuchi...)

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **93**, 011306(R) (2016)

α-decay width of ^{212}Po from a quartetting wave function approach

Chang Xu,[1,*] Zhongzhou Ren,[1,2,†] G. Röpke,[3,‡] P. Schuck,[4,5,§] Y. Funaki,[6] H. Horiuchi,[7,8] A. Tohsaki,[7] T. Yamada,[9] and Bo Zhou[10]

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New insight into alpha clustering of heavy nuclei via their alpha decay, PLB777 (2018) 298-302: Qian and Ren

Physics Letters B 777 (2018) 298–302

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PHYSICS LETTERS B

New insight into α clustering of heavy nuclei via their α decay

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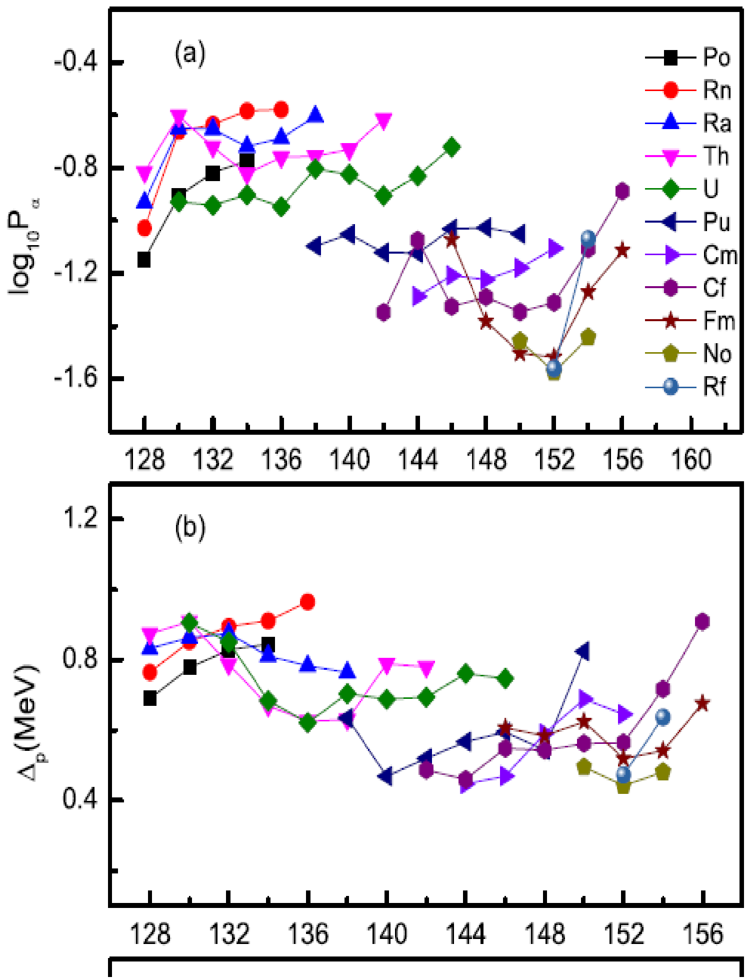
[c] School of Physics Science and Engineering, Tongji University, Shanghai 200092, China



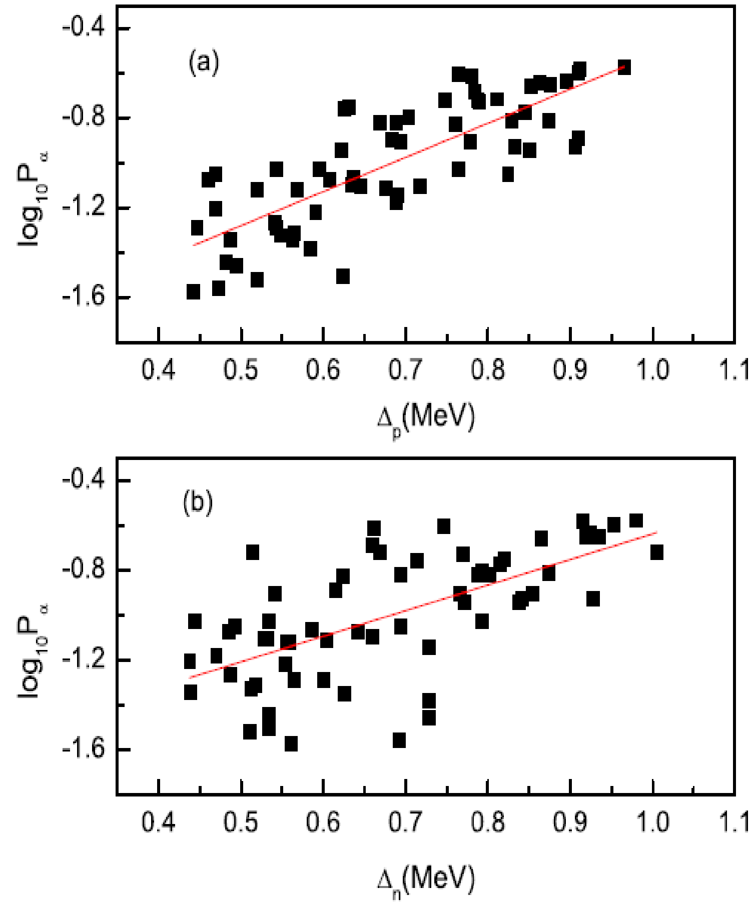
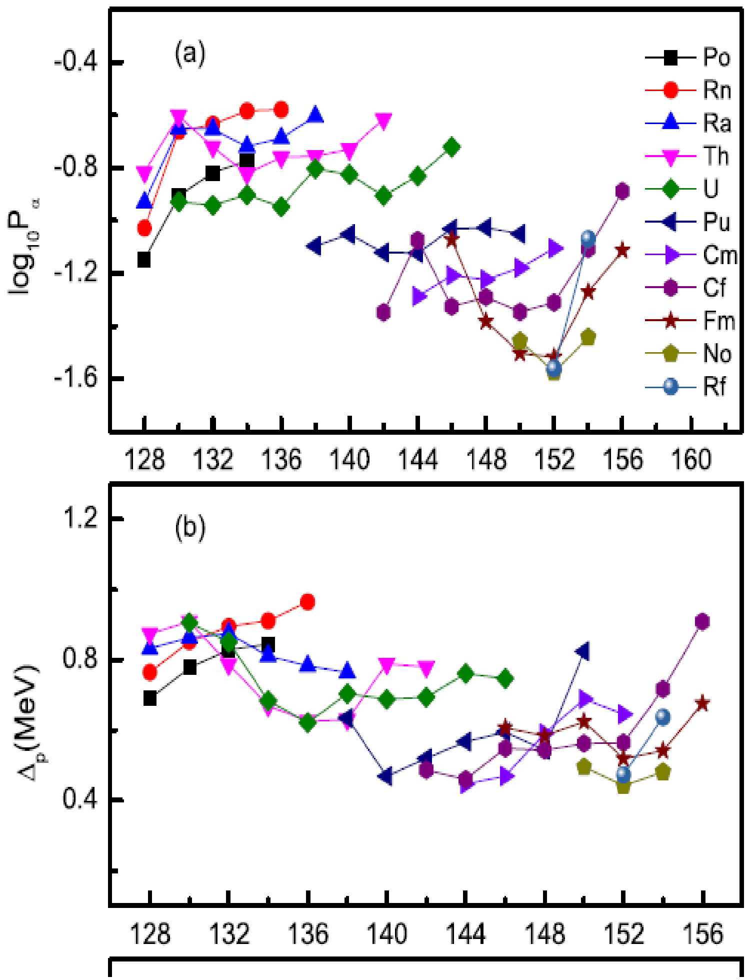


Fig. 3. (a) α preformation factors (in logarithm scale) versus proton pairing gaps of



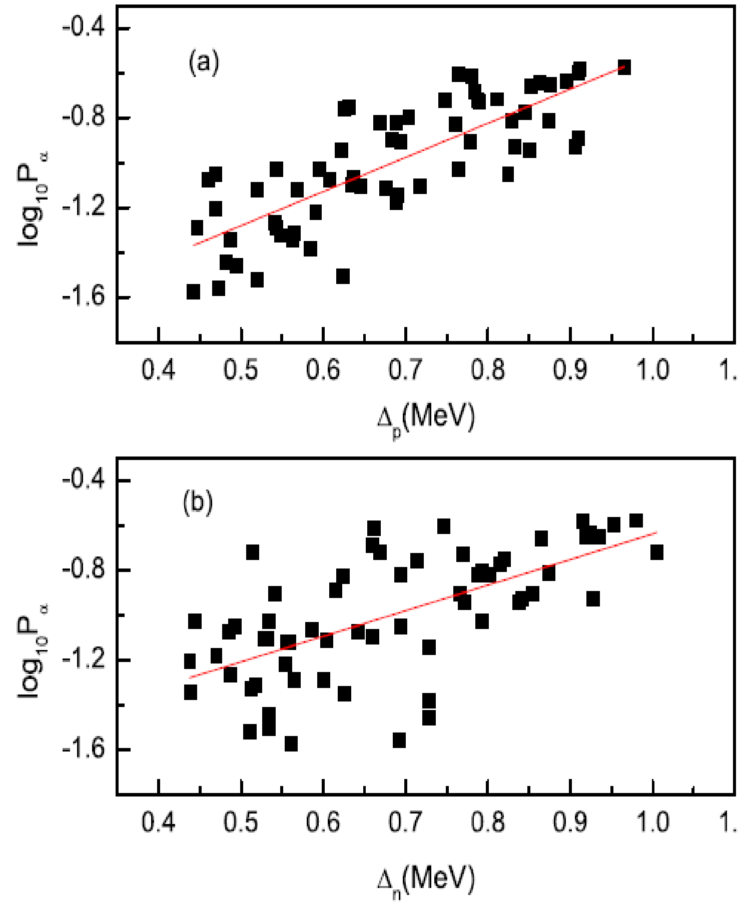


Fig. 3. (a) α preformation factors (in logarithm scale) versus proton pairing gaps of

New result on ^{219}Np, PLB777 (2018) 212-216: …Gan… Zhou, Ren, Zhou , Xu, Xiao

Physics Letters B 777 (2018) 212–216

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Alpha decay properties of the semi-magic nucleus ^{219}Np

Check for updates

H.B. Yang [a], L. Ma [a], Z.Y. Zhang [a], C.L. Yang [a], Z.G. Gan [a,*], M.M. Zhang [a,b], M.H. Huang [a], L. Yu [a], J. Jiang [a], Y.L. Tian [a,b], Y.S. Wang [a,b,c], J.G. Wang [a], Z. Liu [a], M.L. Liu [a], L.M. Duan [a], S.G. Zhou [d], Z.Z. Ren [e,f], X.H. Zhou [a], H.S. Xu [a], G.Q. Xiao [a]

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Summary

- **Density-Dependent Cluster Model (DDCM)**
- **Multi-Channel Cluster Model (MCCM) for calculations of alpha-decay half-lives and branching ratios of deformed nuclei:**

  S-eq. for quasi-bound states.

- **By including nuclear deformation, we reach good agreement with experimental half-lives and branching ratios. Odd-A and odd-odd nucei.**
- **New Geiger-Nuttall law agrees well with half-lives**
- **New isotopes ^{205}Ac and ^{216}U.**

Thanks

- **Collaborators: C.Xu, D.Ni, X.P. Zhang, Y.Qian, Bo Zhou, Mengjiao Lyu, Q. Zhao… Z.Gan…;**

  H. Horiuchi, Tohsaki, Funaki, Yamada，

  Hiyama, En'yo, P. Schuck, G. Roepke, …
-
- **Thanks for your attention ….**

New result on ^{219}Np, PLB777 (2018) 212-216: …Gan…Ren, Zhou …Xiao

A B S T R A C T

The semi-magic nucleus ^{219}Np was produced in the fusion reaction ^{187}Re(^{36}Ar, 4n)^{219}Np at the gas-filled recoil separator SHANS (Spectrometer for Heavy Atoms and Nuclear Structure). A fast electronics system based on waveform digitizers was used in the data acquisition and the sampled pulses were processed by digital algorithms. The reaction products were identified using spatial and time correlations between the implants and subsequent α decays. According to the observed α-decay chain, an energy of E_α = 9039(40) keV and a half-life of $T_{1/2} = 0.15^{+0.72}_{-0.07}$ ms were determined for ^{219}Np. The deduced proton binding energy of ^{219}Np fits well into the systematics, which gives another evidence of that there is no sub-shell closure at $Z = 92$. The influence of the $N = 126$ shell closure on the stability of Np isotopes is discussed within the framework of α-decay reduced widths.

Denisov et al. compared DDCM with their results

PHYSICAL REVIEW C **72**, 064613 (2005)

α-nucleus potential for α-decay and sub-barrier fusion

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The α particles emitted from superheavy elements are considered in recent references [7,16,18,28]. In Fig. 2 we present the results for $\log_{10}(T_{1/2})$ of superheavies using our model and other approaches [7,18,28]. Our results and those from Ref. [18] are obtained by use of different cluster model approaches to the α-decay, whereas results from Refs. [7,28] are evaluated with the help of various empirical relations.

Our results and those from Ref. [18] are …of different cluste model... in Fig. 2.

a rule. Thus, good estimation of the α-decay half-lives for superheavy nuclei in Ref. [18] (see also Fig. 2) is obtained by strong reduction of the nuclear part of the potential calculated from the M3Y nucleon-nucleon force. The strength of the

relations from Ref. [7]. The cluster theory proposed in Ref. [18] describes well $\log_{10}(T_{1/2})$ in this region too.

Good estimation of alpha-decay half-lives is obtained in Ref.[18] for superheavy nuclei...

[18] C. Xu and Z. Ren, Nucl. Phys. A753, 174 (2005)

TABLE I. The logarithm of α-decay half lives of even-even $Z = 84 - 92$ isotopes calculated with new Geiger-Nuttall law (lgT_{theo}) and the corresponding experimental ones (lgT_{expt}). The experimental decay energies of nuclei [Q (MeV)] are also listed in the table.

Nuclei	Q (MeV)	$lgT_{expt}(s)$	$lgT_{theo}(s)$	Nuclei	Q (MeV)	$lgT_{expt}(s)$	$lgT_{theo}(s)$
^{218}Po	6.115	2.27	2.27	^{218}Ra	8.546	–4.59	–4.46
^{216}Po	6.906	–0.84	–0.84	^{216}Ra	9.526	–6.74	–6.93
^{214}Po	7.833	–3.78	–3.86	^{214}Ra	7.273	0.39	0.45
^{212}Po	8.954	–6.52	–6.86	^{206}Ra	7.415	–0.62	–0.05
^{210}Po	5.407	7.08	6.59	^{204}Ra	7.636	–1.22	–0.78
^{208}Po	5.215	7.96	7.60	^{202}Ra	8.020	–2.58	–1.97
^{206}Po	5.327	7.14	7.00	^{232}Th	4.082	17.65	17.56
^{204}Po	5.485	6.28	6.18	^{230}Th	4.770	12.38	12.38
^{202}Po	5.701	5.15	5.12	^{228}Th	5.520	7.78	7.88
^{200}Po	5.981	3.79	3.83	^{226}Th	6.451	3.26	3.43
^{198}Po	6.309	2.27	2.43	^{224}Th	7.298	0.02	0.15
^{196}Po	6.657	0.77	1.06	^{222}Th	8.127	–2.69	–2.56
^{194}Po	6.987	–0.41	–0.14	^{220}Th	8.953	–5.01	–4.87
^{190}Po	7.693	–2.61	–2.45	^{218}Th	9.849	–6.96	–7.04
^{222}Rn	5.590	5.52	5.61	^{216}Th	8.071	–1.57	–1.39
^{220}Rn	6.405	1.75	1.91	^{214}Th	7.826	–1.00	–0.63
^{218}Rn	7.263	–1.46	–1.29	^{212}Th	7.952	–1.44	–1.03
^{216}Rn	8.200	–4.35	–4.20	^{238}U	4.270	17.15	17.17
^{214}Rn	9.208	–6.57	–6.82	^{236}U	4.573	14.87	14.84
^{212}Rn	6.385	3.16	2.99	^{234}U	4.858	12.89	12.85
^{210}Rn	6.159	3.95	3.94	^{232}U	5.414	9.34	9.44
^{208}Rn	6.261	3.37	3.50	^{230}U	5.993	6.25	6.40
^{206}Rn	6.384	2.74	2.99	^{228}U	6.803	2.74	2.82
^{204}Rn	6.546	2.01	2.33	^{226}U	7.701	–0.57	–0.47
^{226}Ra	4.871	10.70	10.67	^{224}U	8.620	–3.03	–3.29
^{224}Ra	5.789	5.50	5.56	^{222}U	9.500	–5.85	–5.59
^{222}Ra	6.679	1.58	1.65	^{218}U	8.786	–2.22	–2.75
^{220}Ra	7.592	–1.75	–1.62				

Different cluster models give similarly good results

PHYSICAL REVIEW C **72**, 064613 (2005)

α-nucleus potential for α-decay and sub-barrier fusion

V. Yu. Denisov[1,2] and H. Ikezoe[1]

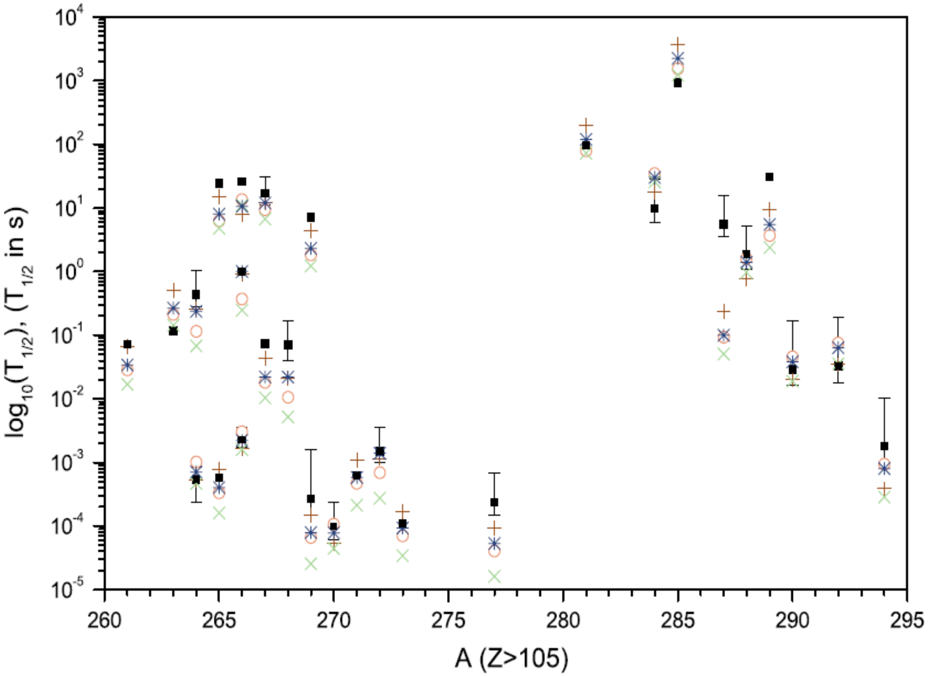

FIG. 2. (Color online) The experimental and theoretical values of $\log_{10}(T_{1/2})$ for superheavy region. Squares with error bars are data from Refs. [13,18], circles are theoretical values obtained by using Eqs. (1)–(9) and (11)–(17), plus and cross signs are the values obtained by using empirical relations from Refs. [7] and [28] respectively, and stars are the results of calculations from Ref. [18].

[18] C. Xu and Z. Ren, Nucl. Phys. **A753**, 174 (2005).

南京大学任中洲课题组 和国外合作

PRL 110, 262501 (2013): 非局域集团新观点

PRL **110,** 262501 (2013) PHYSICAL REVIEW LETTERS week ending 28 JUNE 2013

Nonlocalized Clustering: A New Concept in Nuclear Cluster Structure Physics

Bo Zhou,[1,2,3,*] Y. Funaki,[3,†] H. Horiuchi,[2,4] Zhongzhou Ren,[1,5,‡] G. Röpke,[6] P. Schuck,[7,8] A. Tohsaki,[2] Chang Xu,[1] and T. Yamada[9]

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(Received 5 April 2013; revised manuscript received 17 May 2013; published 24 June 2013)

We investigate the $\alpha + {}^{16}$O cluster structure in the inversion-doublet band ($K^\pi = 0_1^\pm$) states of ^{20}Ne with an angular-momentum-projected version of the Tohsaki-Horiuchi-Schuck-Röpke (THSR) wave function, which was successful "in its original form" for the description of, e.g., the famous Hoyle state. In contrast with the traditional view on clusters as localized objects, especially in inversion doublets, we find that these *single* THSR wave functions, which are based on the concept of nonlocalized clustering, can well describe the $K^\pi = 0_1^-$ band and the $K^\pi = 0_1^+$ band. For instance, they have 99.98% and 99.87% squared overlaps for 1^- and 3^- states (99.29%, 98.79%, and 97.75% for 0^+, 2^+, and 4^+ states), respectively, with the corresponding exact solution of the $\alpha + {}^{16}$O resonating group method. These astounding results shed a completely new light on the physics of low energy nuclear cluster states in nuclei: The clusters are nonlocalized and move around in the whole nuclear volume, only avoiding mutual overlap due to the Pauli blocking effect.

New isotope in China: 265Bh (Z=107)

Eur. Phys. J. A **20**, 385–387 (2004)

THE EUROPEAN PHYSICAL JOURNAL A

Letter

New isotope ^{265}Bh

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Data of 265Bh agree with theory [12,13]

. The derived Q_α from the measured α energy for ^{265}Bh was 9.38 MeV, which was in agreement with the expected Q_α value by Zhongzhou Ren *et al.* [12,13]. The experimental half-life of ^{265}Bh also agrees with the calculations [13] $T_{1/2} = 2.6$

Generalized Density-Dependent Cluster Model
PRC 80 014314 (2009)

PHYSICAL REVIEW C **80**, 014314 (2009)

Exotic α decays around the $N = 126$ magic shell

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(Received 26 May 2009; published 20 July 2009)

We investigate the α-decay half-lives of the exotic $N = 125, 126, 127$ isotones by the generalized density-dependent cluster model (GDDCM) in combination with the microscopic two-level model. The decay widths are calculated using the overlap integral of the quasibound state wave function, the scattering state wave function, and the difference of potentials, instead of using the simple semiclassical WKB method along with the Bohr-Sommerfeld quantization condition. The α-preformation factors are evaluated by the Z-dependent formula based on the two-level model, where the closed-shell effect is included. The calculated half-lives of α transitions to both ground states and excited states are found to be in good agreement with the experimental data.

DOI: 10.1103/PhysRevC.80.014314 PACS number(s): 23.60.+e, 21.10.Tg, 21.60.Gx, 27.80.+w

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **80**, 051303(R) (2009)

Microscopic calculation of α-decay half-lives with a deformed potential

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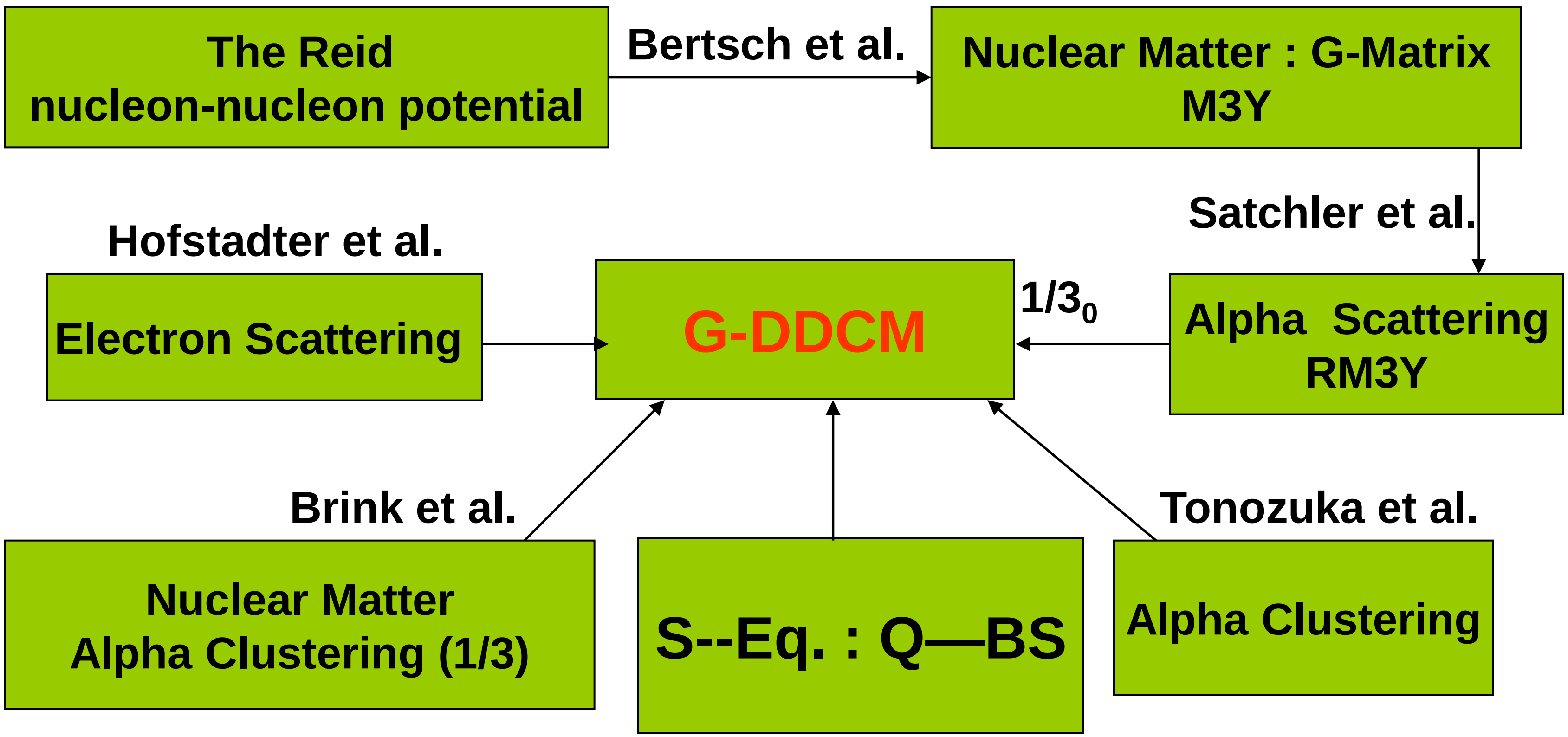
(Received 23 July 2009; revised manuscript received 11 October 2009; published 12 November 2009)

A new version of the generalized density-dependent cluster model is presented to describe an α particle tunneling through a deformed potential barrier. The microscopic deformed potential is numerically constructed in the double-folding model by the multipole expansion method. The decay width is computed using the coupled-channel Schrödinger equation with outgoing wave boundary conditions. We perform a systematic calculation on α-decay half-lives of even-even nuclei ranging from $Z = 52$ to $Z = 104$, including 65 well-deformed ones. The calculated α-decay half-lives are found to be in good agreement with the experimental values. There also exists good agreement with the available experimental branching ratios for well-deformed systems.

Generalized Density-Dependent Cluster Model



Calculated results for two isotopes of Pu

^{240}Pu

	Exp. (%)	Cal. (%)
8^+	4.6×10^{-5}	4.6×10^{-6}
6^+	0.00106	0.00147
4^+	0.084	0.048
2^+	27.1	27.73
0^+	72.8	72.22
$T_{1/2}$(s)	2.07×10^{11}	2.74×10^{11}

^{242}Pu

	Exp. (%)	Cal. (%)
8^+	---	2.6×10^{-6}
6^+	0.00086	0.00232
4^+	0.0307	0.0341
2^+	23.48	23.85
0^+	76.49	76.12
$T_{1/2}$(s)	1.18×10^{13}	1.93×10^{13}

Quantum Mechanics (QM)：quantization and Schrodinger-eq.

- Geiger-Nuttall law (G-N law) was proposed （1911 ） before QM (1925-1927)
- Gamow derived G-N law but without introducing quantum numbers.
- Change of quantum numbers should be included in G-N law as alpha-decay is a pure quantum effect.

Some basic observables such as quantum numbers can be absorbed in the formula for a better description of alpha-decay data.

$$\left\{-\frac{\hbar^2}{2\mu}\frac{d^2}{dr^2}-\left[V_N(r)+V_C(r)+\frac{\ell(\ell+1)\hbar^2}{2\mu r^2}\right]\right\}u_{n\ell j}(r)=E\ u_{n\ell j}(r)$$

$$G=2n+\ell=\sum_{i=1}^{4}g_i^{A_c}$$

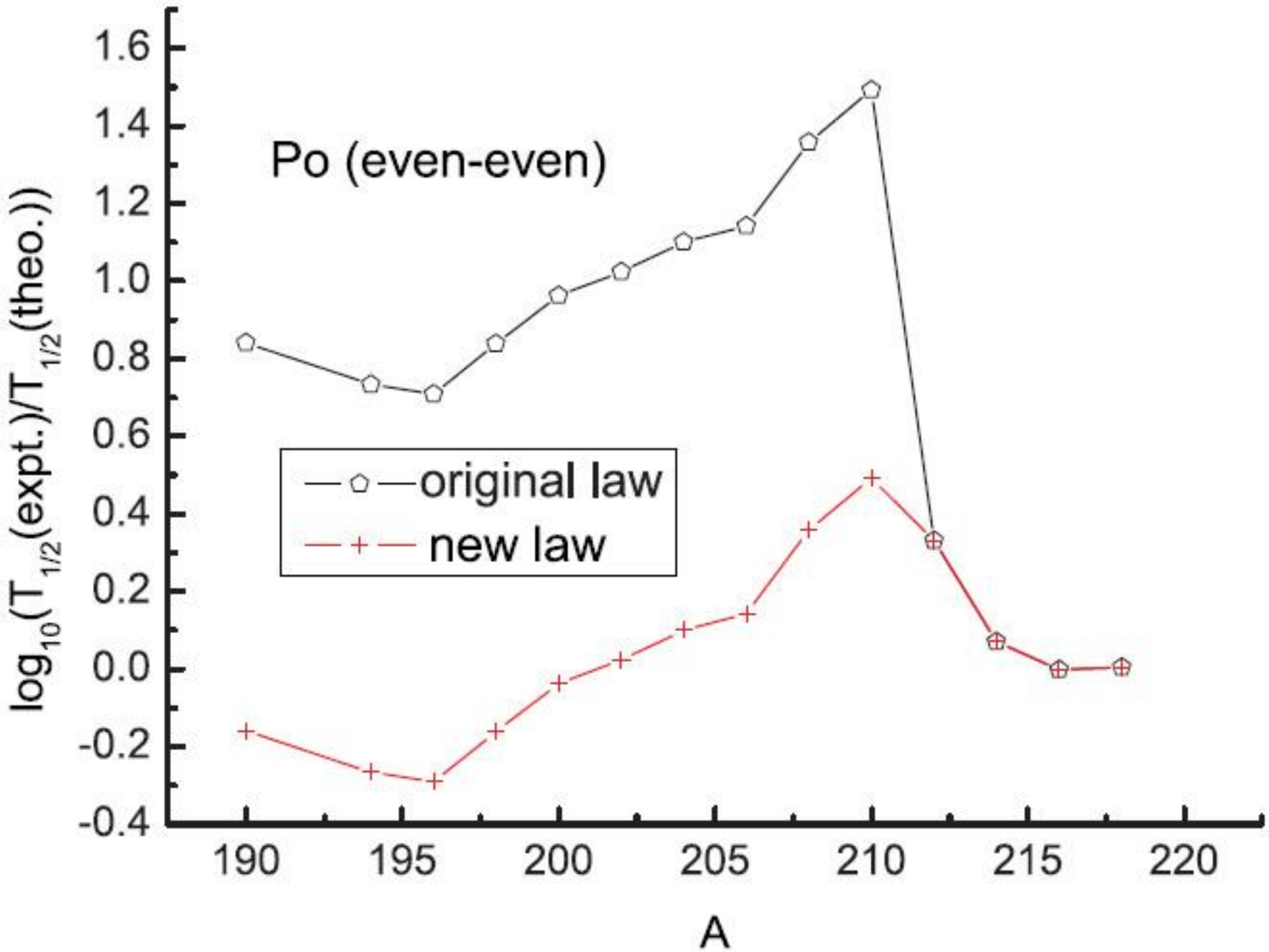
Ground-state transition of even-even nuclei : L=0

$$\log_{10}T_{1/2}=a\sqrt{\mu}Z_cZ_d/\sqrt{Q}+b\sqrt{\mu}\sqrt{Z_cZ_d}+c+S+P\ell(\ell+1)$$

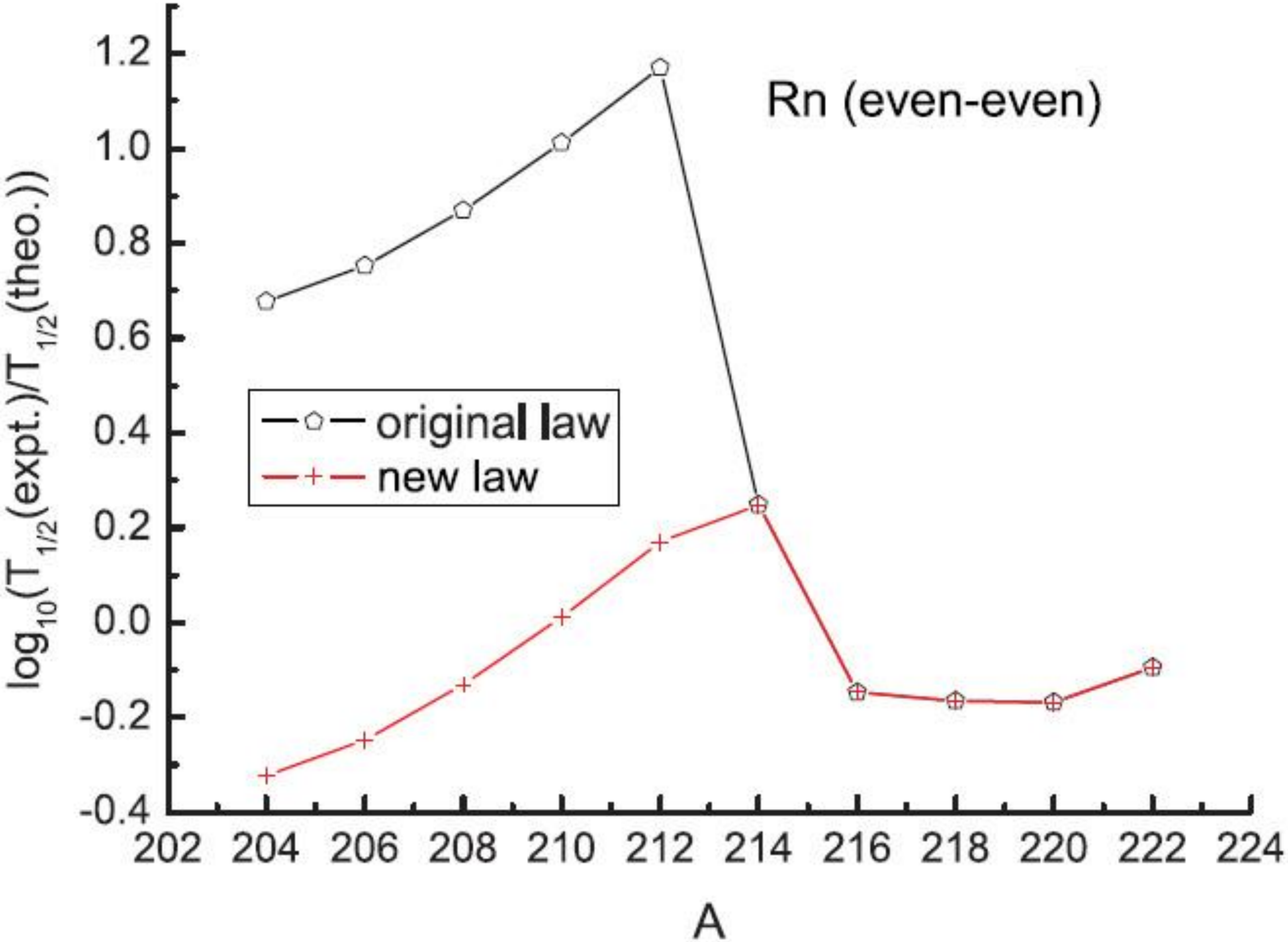
Effects of *G* (or *n*) quantum number on alpha-decay data: S=0 for N>126 and S=1 for N<=126

Effects of angular momentum and parity of alpha particle

Ratios between experiment and theory for even-even Po nuclei with the original law and with the new law: new law also agrees well with the data for N<=126.



Ratios between experimental data and theoretical results for Rn nuclei with the original law and with the new law (PRC, 2012)



Ratios between experimental data and theoretical results for odd-A Po nuclei with original law and with new law (PRC, 2012)

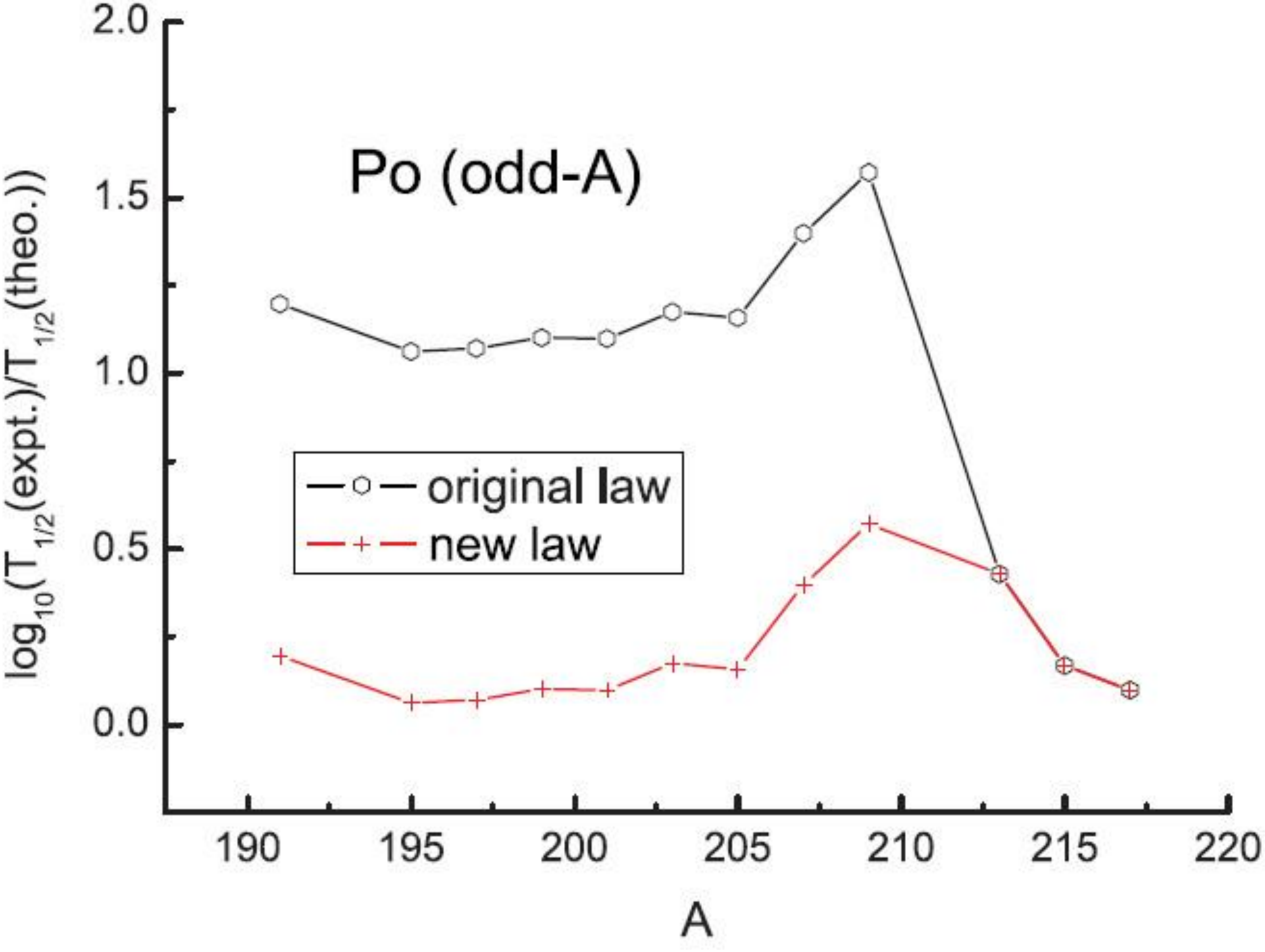
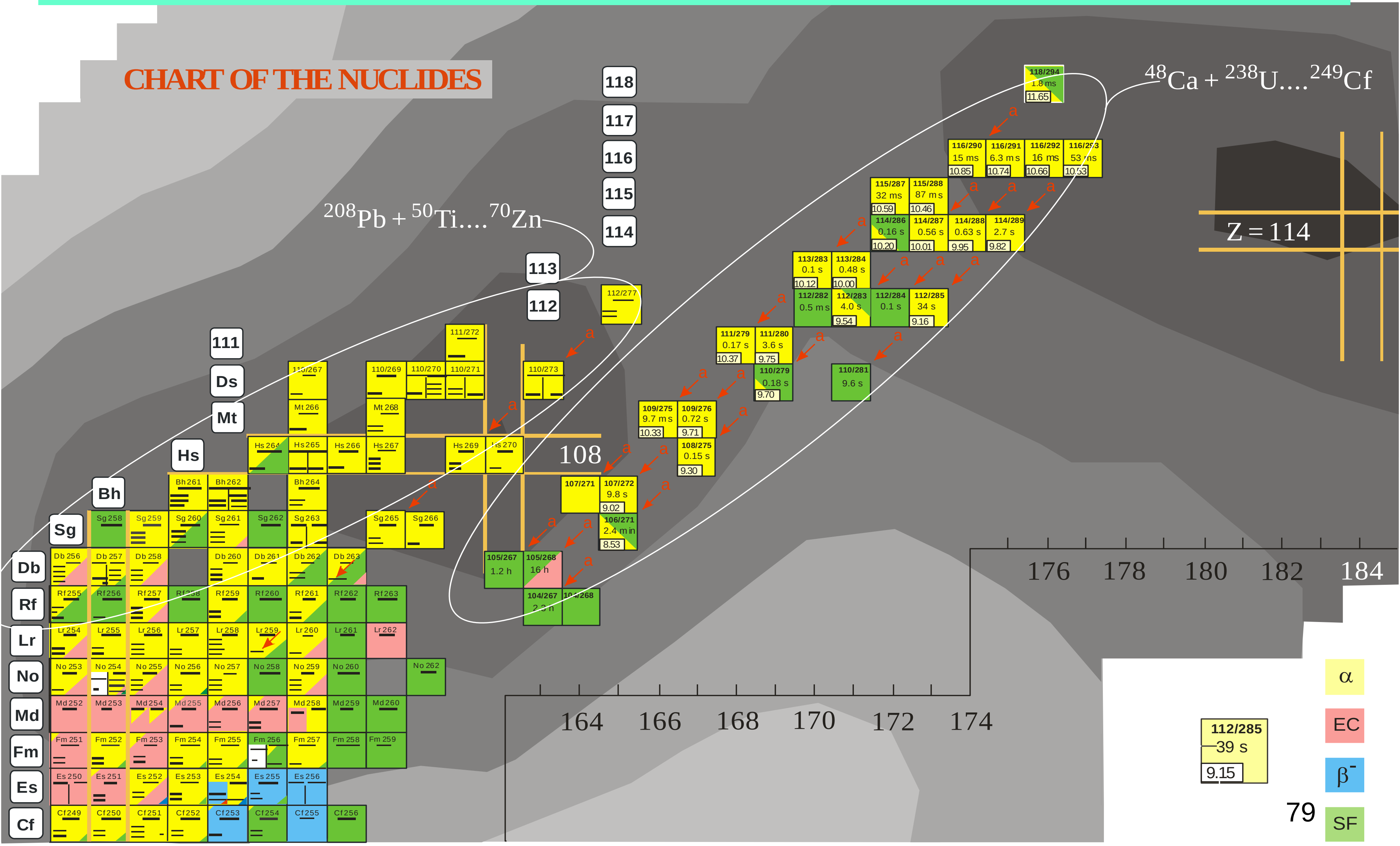


TABLE II. The logarithm of α-decay half-lives of even-even $Z = 60$–74 isotopes calculated with new Geiger-Nuttall law (lgT_{theo}) and the corresponding experimental ones (lgT_{expt}). The experimental decay energies of nuclei [Q (MeV)] are also listed in the table.

Nuclei	Q (MeV)	$lgT_{expt}(s)$	$lgT_{theo}(s)$
^{168}W	4.506	6.20	6.50
^{166}W	4.856	4.74	4.53
^{164}W	5.2785	2.22	2.41
^{162}W	5.6773	0.48	0.64
^{160}W	6.065	–0.99	–0.91
^{158}W	6.613	–2.86	–2.86
^{162}Hf	4.417	5.69	5.95
^{160}Hf	4.9024	3.29	3.28
^{158}Hf	5.4047	0.80	0.90
^{156}Hf	6.028	–1.62	–1.62
^{158}Yb	4.172	6.63	6.36
^{156}Yb	4.811	2.42	2.75
^{154}Yb	5.4742	–0.35	–0.31
^{156}Er	3.487	9.84	10.04
^{154}Er	4.2799	4.68	4.61
^{152}Er	4.9344	1.06	1.15
^{154}Dy	2.946	13.98	13.56
^{152}Dy	3.726	6.93	7.04
^{150}Dy	4.3513	3.08	3.13
^{152}Gd	2.203	21.53	21.09
^{150}Gd	2.808	13.75	13.56
^{148}Gd	3.27121	9.37	9.26
^{148}Sm	1.9861	23.34	22.81
^{146}Sm	2.5284	15.51	15.17
^{144}Nd	1.9052	22.86	22.40

Alpha decay: a reliable way to identify new synthesized elements.



Calculated results for two isotopes of Cm

^{242}Cm

Final state	*Exp.* (%)	*Cal.* (%)
8^+	2.0×10^{-5}	3.8×10^{-5}
6^+	0.0046	0.0053
4^+	0.035	0.077
2^+	25.92	31.04
0^+	74.08	68.87
$T_{1/2}$(s)	1.41×10^{7}	1.32×10^{7}

^{244}Cm

Final state	*Exp.* (%)	*Cal.* (%)
8^+	4.0×10^{-5}	2.8×10^{-5}
6^+	0.00352	0.00733
4^+	0.0204	0.0479
2^+	23.1	28.60
0^+	76.9	71.34
$T_{1/2}$(s)	5.72×10^{8}	5.68×10^{8}

Five-channel calculation of fine structure in the alpha decay of well-deformed nuclei

PHYSICAL REVIEW C **83**, 067302 (2011)

Coupled-channels study of fine structure in the α decay of well deformed nuclei

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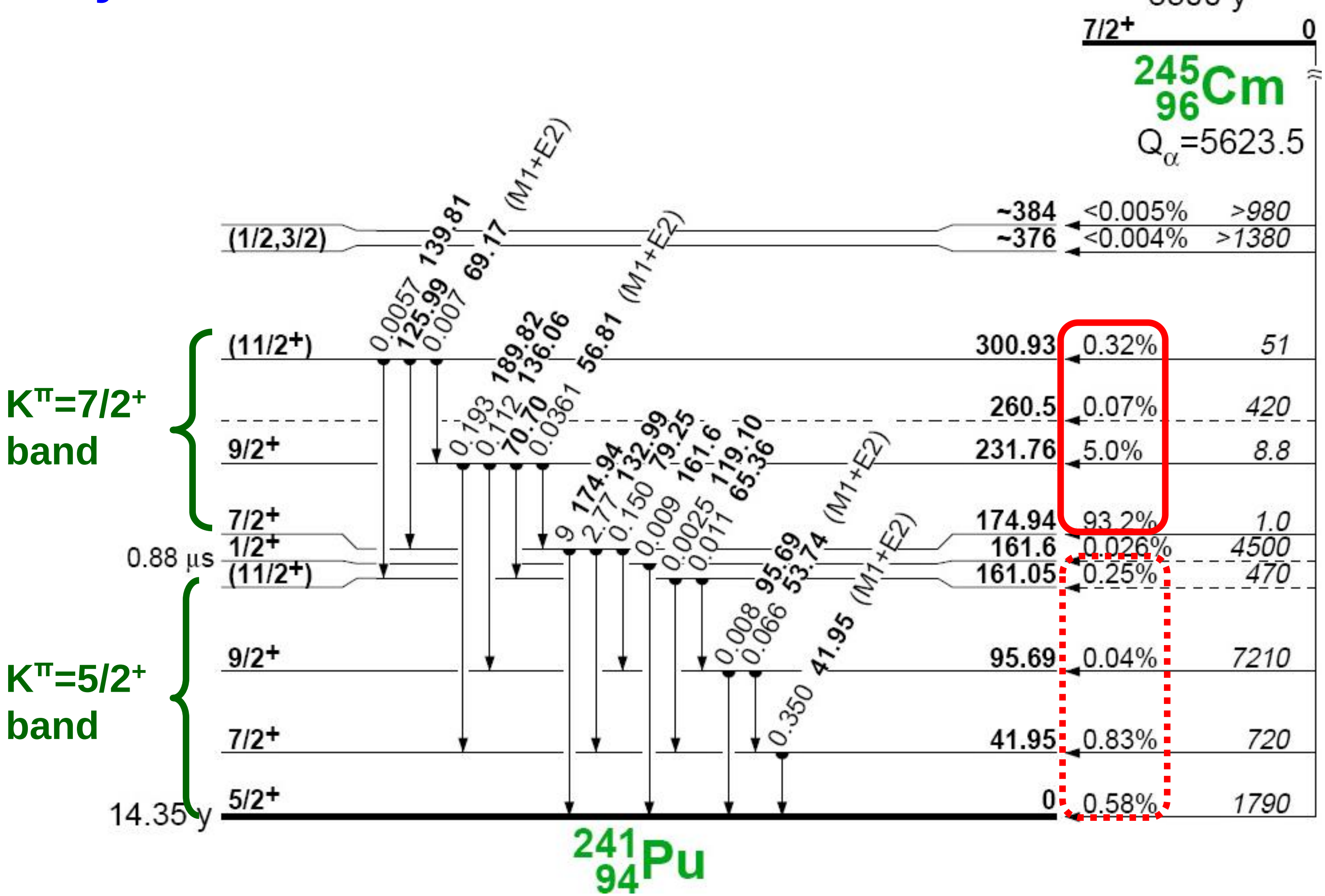
(Received 14 March 2011; revised manuscript received 8 June 2011; published 21 June 2011)

We formulate a theoretical model for the α decay of well-deformed even-even nuclei based on the coupled-channel Schrödinger equation. The α-decay half-lives and fine structures observed in α decay are well described by the five-channel microscopic calculations. Since the branching ratios to high-spin states are hard to understand in the traditional α-decay theories, this success could be important to interpret future observations of heavier nuclei. It is also found that the α transition to high-spin states is a powerful tool to probe the energy spectrum and deformation of daughter nuclei.

Experimental observation of fine structure in the alpha decay of odd-mass nuclei: ^{245}Cm



Qian and Ren, PLB 738 (2014) 87-91:

Half-lives of α-decay from superheavy elements

Physics Letters B 738 (2014) 87–91

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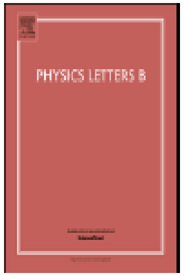

Half-lives of α decay from natural nuclides and from superheavy elements

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Microscopic calculations of α preformation factor in ^{212}Po (PRC 2016, Xu, Ren,…)

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **93**, 011306(R) (2016)

α-decay width of ^{212}Po from a quartetting wave function approach

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New result on ^{219}Np, PLB777 (2018) 212-216: …Gan…Ren, Zhou ,Xu,Xiao

Physics Letters B 777 (2018) 212–216

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PHYSICS LETTERS B

Alpha decay properties of the semi-magic nucleus ^{219}Np

Check for updates

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