南華大學
UNIVERSITY OF SOUTH CHINA

壳附近原子核α衰变预形成因子系统行为研究

李 小 华

南华大学

合作者：孙小东、邓军刚、刘宏铭、包小军、初鹏程

@绵阳 2020.1.13

outline

- The theoretical models of α decay
- The α preformation probability（P_α)
- The two-potential-approach for P_α
- The cluster-formation model for P_α
- Our works
- Summary

1. The theoretical models of alpha decay

- α decay has long been perceived as one of the most powerful tools to investigate unstable nuclei, neutron-deficient nuclei, and superheavy nuclei.
- Within Gamow's theory, the α decay process is described as a preformed α particle penetrating the Coulomb barrier.

$$T_{1/2} = \frac{\hbar \ln 2}{\Gamma} = \frac{\ln 2}{\lambda} \qquad \lambda = P_\alpha \nu P$$

P_α denotes α preformation factors,

ν is the assault frequency of α particle,

P denote the semiclassical Wentzel-Kramers-Brillouin (WKB) barrierpenetrate probability.

1. The theoretical models of alpha decay

The theoretical models of alpha decay:

I. The cluster model (CM), density-dependent cluster model (DDCM)

任中洲老师课题组:

C. Xu and Z. Ren, Phys. Rev. C 73, 041301 (2006)

C. Xu and Z. Ren, Nucl. Phys. A 760, 303 (2005)……

II. The unified fission model (UFM)

左维老师课题组:

J. Dong,W. Zuo, J. Gu, Y.Wang, and B. Peng, Phys. Rev. C 81, 064309 (2010) ……

III. Generalized Liquid Drop Model (GLDM)

张鸿飞老师课题组:

H. Zhang,W. Zuo, J. Li, and G. Royer, Phys. Rev. C 74, 017304 (2006)

H. F. Zhang and G. Royer, Phys. Rev. C 77, 054318 (2008) ……

1. The theoretical models of alpha decay

IV. The relativistic mean field model (RMF)

龙文辉老师课题组:

W. Long, J. Meng, and S.-G. Zhou, Phys. Rev. C 65, 047306 (2002) ······

VI. The Coulomb and proximity potential model (CPPM)

张高龙老师课题组:

Y. J. Yao, G. L. Zhang, W. W. Qu and J. Q. Qian, Eur. Phys. J. A 51, 122 (2015)

C. L. Guo, G. L. Zhang and X. Y. Le, Nucl. Phys. A 897, 54 (2013)

VI. Empirical Formulas (EF)

许甫荣老师课题组: C. Qi, F. R. Xu, R. J. Liotta, and R. Wyss, Phys. Rev. Lett. 103, 072501 (09)······

郭建友老师课题组: Z. Y. Wang, Z. M. Niu, Q. Liu and J. Y. Guo, J. Phys. G: Nucl. Part. Phys. 42, 055112 (2015) ······

......

2. The α preformation probability（P_α）

Microscopic methods for obtaining P_α

a) Microscopically, α preformation probabilities can be evaluated through an overlap between the initial state and the α-decaying state. [Phys. Rep. 294 （1998） 265]
b) The approach of the Tohsaki-Horiuchi-Schuck-Ropke wave function was used to calculate the α preformation probability. [Phys. Rev. C 90 (2014) 034304，Phys. Rev. C 93, (2016) 011306(R)]
c) The shell model to obtain the α preformation probability.[Phys. Rev. Lett. 69 (1992) 37,Nucl. Phys. A 550(1992)421]
d) The cluster-formation model to obtain the α preformation probability.[Rom. Rep. Phys. 65 (2013) 1281，J. Phys. G 40（2013）065105，Phys. Rev. C 93 (2016) 044326]

2. The α preformation probability（P_{α}）

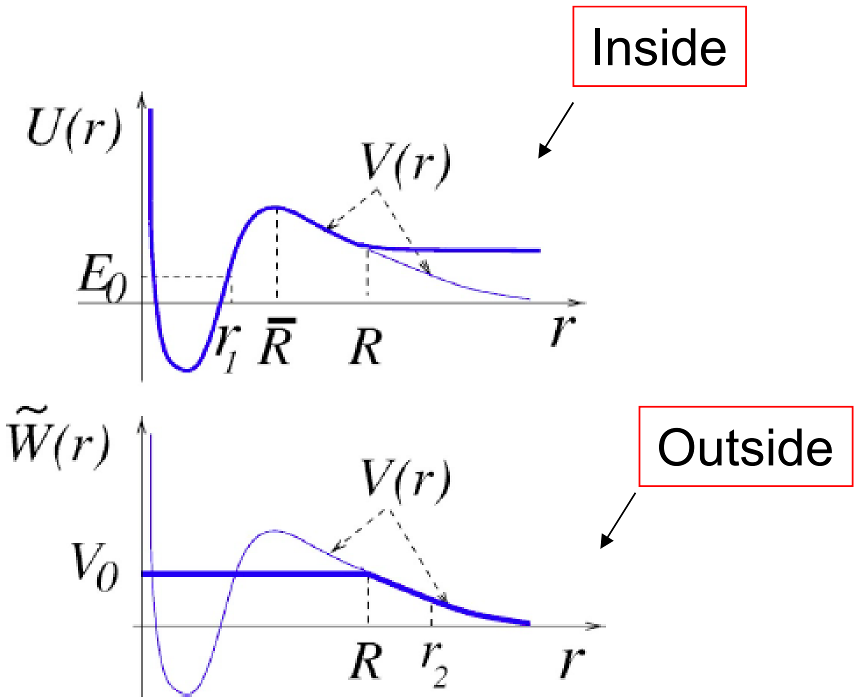
Experimental methods for obtaining P_{α}

$$P_{\alpha} = \frac{\mathrm{T_{cal}}}{\mathrm{T_{exp}}}$$

T_{cal} Where is the calculated values without taking P_{α}

3. The two-potential-approach for P_α

Two-Potential Approach(TPA)



$$U(r)=\begin{cases} V(r) & for \quad r \le R, \\ V(R) & for \quad r > R \end{cases}$$

$$\tilde{W}(r)=\begin{cases} V_0 & for \quad r \le R, \\ V(r) & for \quad r > R \end{cases}$$

Phys. Rev. Lett. 59(1987)262
Phys. Rev. A 69(2004)042705

3. The two-potential-approach for P_α

α-decay half-lives
$$T_{1/2} = \frac{\hbar \ln 2}{\Gamma} = \frac{\ln 2}{\lambda}$$

α-decay width
$$\Gamma = \frac{P_\alpha F P}{4\mu}$$

The normalized factor
$$F \int_{r1}^{r_2} \frac{dr}{2k(r)} = 1$$

The wave number
$$k(r) = \sqrt{\frac{2\mu}{\hbar^2} |Q_\alpha - V(r)|}$$

The penetration probability
$$P = \exp[-2\int_{r_2}^{r_3} k(r) dr]$$

Classical turning points:
$$V(r_1) = V(r_2) = V(r_3) = Q_\alpha$$

3. The two-potential-approach for P_α

The α-daughter nuclei potential

$$V(r)=V_N(r)+V_C(r)+V_l(r)$$

I. Nuclear potential

$$V_N(r)=-\mathrm{V}_0\frac{1+\cosh(R/a)}{\cosh(\mathrm{r}/a)+\cosh(R/a)}$$

II. Coulomb potential

$$V_C(r)=\begin{cases}\dfrac{Z_1Z_2e^2}{2R}[3-(\dfrac{r}{R})^2] & r\le R\\ \dfrac{Z_1Z_2e^2}{r} & r>R\end{cases}$$

3. The two-potential-approach for P_α

III. Centrifugal potential

$$V_l(r) = \frac{l(l+1)\hbar^2}{2\mu r^2}$$

The sharp radius

$$R = 1.28A^{1/3} - 0.76 + 0.8A^{-1/3}$$

4. The cluster-formation model for P_α

IOP PUBLISHING JOURNAL OF PHYSICS G: NUCLEAR AND PARTICLE PHYSICS
J. Phys. G: Nucl. Part. Phys. **40** (2013) 065105 (22pp) doi:10.1088/0954-3899/40/6/065105

Alpha-cluster preformation factors in alpha decay for even–even heavy nuclei using the cluster-formation model

Saad M Saleh Ahmed, Redzuwan Yahaya, Shahidan Radiman and Muhamad Samudi Yasir

School of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

E-mail: saadtm2000@gmail.com

penetrability was used. Such calculations reflect information about the clustered alpha but not about the mechanism of alpha clustering.

In a previous work [43], we have proposed a new simple model, called the cluster-formation model (CFM), to determine the preformation factor and the clustering amount (CA) of an alpha cluster for ^{212}Po. The determined alpha clustering value was in agreement with that of Varga *et al* (1992) [1, 5], and the preformation factor was in agreement with the value that Ni and Ren [44] extracted by fitting the experimental alpha-decay width to their microscopic calculations for a wide range of nuclei. This agreement motivated us to use the CFM to

4. The cluster-formation model for P_α

- **Ahmed** et al. presented a **new quantum mechanical theory** named cluster-formation model (**CFM**) to calculate the α preformation factors P_α of **even-even nuclei**, which suggests that the initial state of the parent nucleus should be a linear combination of different possible clusterization states.
- Very recently, **Ahmed et al.** and **Deng et al.** extended CFM to **odd-A and doubly odd nuclei** through modifying the formation energy of the interior α cluster for various types of nuclei (i.e., **even-Z–odd-N, odd-Z–even-N, and doubly odd nuclei**) and considering the effects of unpaired nucleon.

References：

[1] S. M. S. Ahmed, R. Yahaya, and S. Radiman, Rom. Rep. Phys. 65, 1281 (2013).

[2] S. M. S. Ahmed, R. Yahaya, S. Radiman, and M. S. Yasir, J. Phys. G 40, 065105 (2013).

[3] S. M. S. Ahmed, Nucl. Phys. A 962, 103 (2017).

[4] D. Deng, Z. Ren, D. Ni, and Y. Qian, J. Phys. G 42, 075106 (2015).

[5] D. Deng and Z. Ren, Phys. Rev. C 93, 044326 (2016).

4. The cluster-formation model for P_α

The theoretical framework of the CFM :

the total clusterization state of parent nuclei: $\Psi = \sum_{i=1}^{n} a_i \Psi_i$

the superposition coefficient of Ψ_i: $a_i = \int \Psi_i^* \Psi d\tau$

orthogonality condition: $\sum_{i=1}^{n} |a_i|^2 = 1$

total Hamiltonian: $H = \sum_{i=1}^{n} H_i$

the total energy: $E = \sum_{i=1}^{n} |a_i|^2 E = \sum_{i=1}^{n} E_{f_i}$

E_{f_i} denotes the formation energy of cluster in the *ith* clusterization state Ψ_i:

the α preformation factor: $P_\alpha = |a_\alpha|^2 = \frac{E_{f\alpha}}{E}$

E_{f_α} is the formation energy of the α cluster. E is composed of the E_{f_α} and the interaction energy between α cluster and daughter nuclei.

4. The cluster-formation model for P_α

For the even-even nuclei

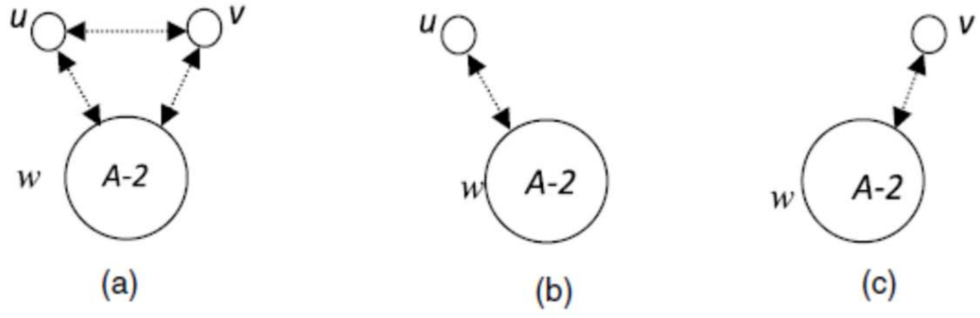


Figure 3. The interactions (a) among the nucleus of A–2 and the two nucleons u and v, (b) between the nucleus A–2 and the nucleon u, and (c) between the nucleus A–2 and the nucleon v.

$$E_{u-v} + E_{u-w} + E_{v-w} = B(A) - B(A-2)$$

For $v = p, \quad u = n$

$$E_{p-n} = B(A,Z) - B(A-2,Z-1) - B(A-1,Z)$$

$$E_{p-p} = B(A,Z) + B(A-2,Z-2) - 2B(A-1,Z-1)$$

$$E_{n-n} = B(A,Z) + B(A-2,Z) - 2B(A-1,Z)$$

4. The cluster-formation model for P_α

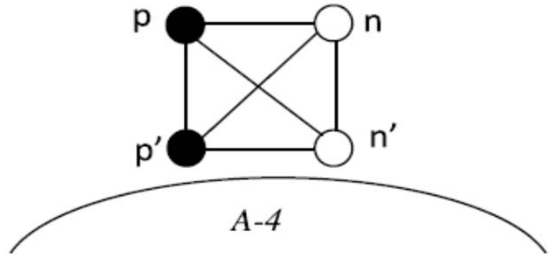


Figure 6. The correlations among the last four nucleons.

$$B(A,Z)=B(A-4,Z-2)+S_\alpha+E_{p-p}+E_{n-n}+E_{2p-2n}$$

$$=B(A-4,Z-2)+E_{p-p}+E_{n-n}+E_{2p-2n}$$

$$+S_{2p}(A-2,Z)+S_{2n}(A-2,Z-2)$$

4. The cluster-formation model for P_α

The formation energy $E_{f\alpha}$

$$E_{f\alpha} = E_{2p-2n} + E_{p-p} + E_{n-n} = E_{\alpha d} - S_\alpha$$

With $E_{\alpha d}$ and S_α being the alpha-decay energy and the separation energy of alpha particle

$$E_{\alpha d} = B(A, Z) - B(A-4, Z-2)$$

$$S_\alpha = B(A-4, Z-2) + B(\alpha) - B(A, Z)$$

4. The cluster-formation model for P_α

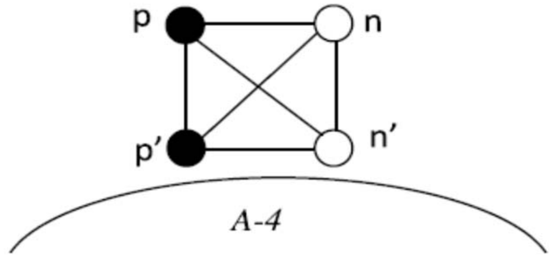


Figure 6. The correlations among the last four nucleons.

$$S_{2p}(A-2,Z)=S_p(A-3,Z-1)+S_{p'}(A-3,Z-1)$$
$$=B(A-2,Z)-B(A-4,Z-2)-E_{p-p}$$

$$S_{2n}(A-2,Z)=B(A-2,Z)-B(A-4,Z-2)-E_{n-n}$$

$$S_p(A-3,Z-1)=S_p(A-2,Z)-E_{p-p'}$$

$$S_n(A-3,Z-2)=S_p(A-2,Z-2)-E_{n-n'}$$

4. The cluster-formation model for P_α

$$E_{2p-2n} = B(A, Z) + B(A-4, Z-2) - B(A-2, Z-2) - B(A-2, Z)$$

$$E_{f\alpha} = 3B(A, Z) + B(A-4, Z-2) - 2B(A-1, Z-1) - 2B(A-1, Z)$$

$$E = B(A, Z) - B(A-4, Z-2)$$

4. The cluster-formation model for P_α

- **Case I for even-even nuclei:**

$$E_{f\alpha} = 3B(A,Z) + B(A-4,Z-2) - 2B(A-1,Z-1) - 2B(A-1,Z)$$
$$E = B(A,Z) - B(A-4,Z-2)$$

- **Case II for even Z-odd N, i.e., even-odd nuclei:**

$$E_{f\alpha} = 3B(A-1,Z) + B(A-5,Z-2) - 2B(A-2,Z-1) - 2B(A-2,Z)$$
$$E = B(A,Z) - B(A-5,Z-2)$$

- **Case III for odd Z-even N, i.e., odd-even nuclei:**

$$E_{f\alpha} = 3B(A-1,Z-1) + B(A-5,Z-3) - 2B(A-2,Z-2) - 2B(A-2,Z-1)$$
$$E = B(A,Z) - B(A-5,Z-3)$$

- **Case IV for doubly odd nuclei:**

$$E_{f\alpha} = 3B(A-2,Z-1) + B(A-6,Z-3) - 2B(A-3,Z-2) - 2B(A-3,Z-1)$$
$$E = B(A,Z) - B(A-6,Z-3)$$

南華大學
UNIVERSITY OF SOUTH CHINA

5. Our works

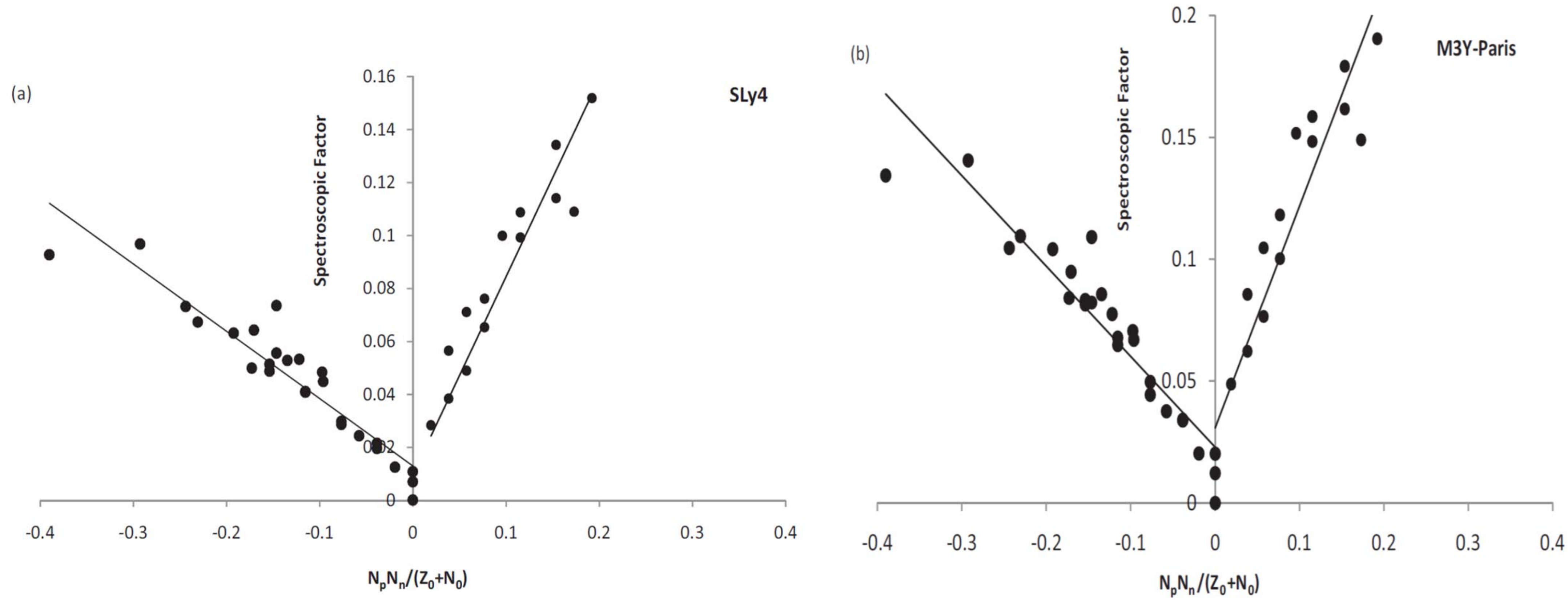
PHYSICAL REVIEW C **84**, 064608 (2011)

Isospin asymmetry dependence of the α spectroscopic factor for heavy nuclei

W. M. Seif,[1] M. Shalaby,[2] and M. F. Alrakshy[2,3]
[1]*Cairo University, Faculty of Science, Department of Physics, Giza 12613, Egypt*
[2]*Ain Shams University, Faculty of Science, Department of Physics, Cairo, Egypt*
[3]*7th of October University, Faculty of Science and Art, Zliten, Libya*
(Received 13 September 2011; revised manuscript received 18 October 2011; published 15 December 2011)

Both the valence nucleons (holes) and the isospin asymmetry dependencies of the preformation probability of an α-cluster inside parents radioactive nuclei are investigated. The calculations are employed in the framework of the density-dependent cluster model of an α-decay process for the even-even spherical parents nuclei with protons number around the closed shell $Z_0 = 82$ and neutrons number around the closed shells $Z_0 = 82$ and $Z_0 = 126$. The microscopic α-daughter nuclear interaction potential is calculated in the framework of the Hamiltonian energy density approach based on the SLy4 Skyrme-like effective interaction. Also, the calculations based on the realistic effective M3Y-Paris nucleon-nucleon force have been used to confirm the results. The calculations then proceed to find the assault frequency and the α penetration probability within the WKB approximation. The half-lives of the different mentioned α decays are then determined and have been used in turn to find the α spectroscopic factor. We found that the spectroscopic factor increases with increasing the isospin asymmetry of the parent nuclei if they have valence protons and neutrons. When the parent nuclei have neutron or proton holes in addition to the valence protons or neutrons, then the spectroscopic factor is found to decrease with increasing isospin asymmetry. The obtained results show also that the deduced spectroscopic factors follow individual linear behaviors as a function of the multiplication of the valence proton (N_p) and neutron (N_n) numbers. These linear dependencies are correlated with the closed shells core (Z_0, N_0). The same individual linear behaviors are obtained as a function of the multiplication of N_pN_n and the isospin asymmetry parameter, N_pN_nI. Moreover, the whole deduced spectroscopic factors are found to exhibit a nearly general linear trend with the function $N_pN_n/(Z_0 + N_0)$.

5. Our works



Even-Even for Z_0=82,N_0=126

南華大學
UNIVERSITY OF SOUTH CHINA

5. Our works

PHYSICAL REVIEW C **94**, 024338 (2016)

Systematic study of favored α-decay half-lives of closed shell odd-A and doubly-odd nuclei related to ground and isomeric states

Xiao-Dong Sun,[1] Ping Guo,[1] and Xiao-Hua Li[2,3,*]
[1]*School of Math and Physics, University of South China, 421001 Hengyang, People's Republic of China*
[2]*School of Nuclear Science and Technology, University of South China, 421001 Hengyang, People's Republic of China*
[3]*Cooperative Innovation Center for Nuclear Fuel Cycle Technology & Equipment, University of South China, 421001 Hengyang, People's Republic of China*

(Received 20 June 2016; published 25 August 2016)

$$P_\alpha = P_0 \frac{T_{1/2}^{calc}}{T_{1/2}^{expt}} \qquad P_\alpha = a\frac{N_p N_n}{Z_0 + N_0} + b \qquad P_\alpha = cN_pN_nI + d$$

P_α is **model-dependent** and **phenomenological**

$T_{1/2}^{calc}$ is calculated by two-potential approach

$\boldsymbol{P_0}$ **is obtained by DDCM**, C. Xu and Z. Ren, Nucl. Phys. A **760**, 303 (2005).

5. Our works

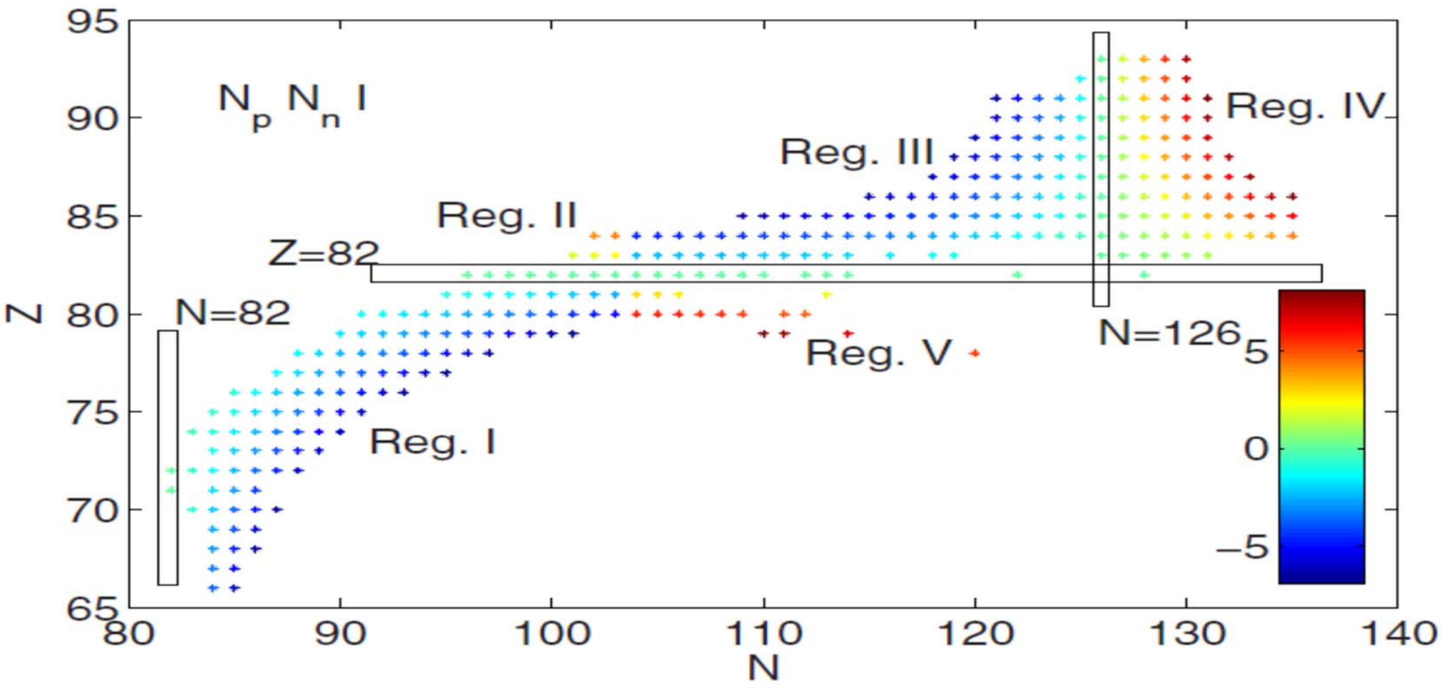


FIG. 2. The colormap of $N_p N_n I$ as a function of neutron numbers N and proton numbers Z of the parent nuclei. The rectangles denote the nuclear shell closures at $Z = 82$ and $N = 82$, 126, and the nuclide chart is divided into five regions.

5. Our works

TABLE III. The parameters of Eqs. (9) and (10) that show α preformation probabilities are linearly related to the valence proton-neutron interaction.

	Eq. (9)		Eq. (10)	
Region	a	b	c	d
		Odd-A nuclei		
I	−1.162	0.137	−0.055	0.162
III	−1.409	0.068	−0.043	0.069
IV	8.230	0.094	0.212	0.086
		Doubly-odd nuclei		
I	−1.831	0.093	−0.011	0.154
III	−3.477	−0.006	−0.128	−0.021
IV	6.676	0.105	0.112	0.137

$$P_\alpha = a\frac{N_p N_n}{Z_0 + N_0} + b$$

$$P_\alpha = cN_pN_nI + d$$

$$Z_0 = 82\ ,\ N_0 = 82{,}126,$$
$$N_p = Z - Z_0,\ N_n = N - N_0$$

I is the asymmetry between neutron and proton in parent nuclei

5. Our works

PHYSICAL REVIEW C **96**, 024318 (2017)

Systematic study of unfavored α-decay half-lives of closed-shell nuclei related to ground and isomeric states

Jun-Gang Deng,[1] Jie-Cheng Zhao,[1] Dong Xiang,[1,*] and Xiao-Hua Li[1,2,3,†]
[1]*School of Nuclear Science and Technology, University of South China, 421001 Hengyang, People's Republic of China*
[2]*Cooperative Innovation Center for Nuclear Fuel Cycle Technology & Equipment, University of South China, 421001 Hengyang, People's Republic of China*
[3]*Key Laboratory of Low Dimensional Quantum Structures and Quantum Control, Hunan Normal University, 410081 Changsha, People's Republic of China*

(Received 5 June 2017; published 22 August 2017)

$$P_\alpha = P_0 \frac{T_{1/2}^{calc}}{T_{1/2}^{expt}}$$

$$P_\alpha = a\frac{N_p N_n}{Z_0 + N_0} + b$$

$$P_\alpha = cN_p N_n I + d$$

P_α is **model-dependent** and **phenomenological**

TABLE IV. The parameters of Eqs. (11) and (12) that show α preformation probabilities are linearly related to $N_p N_n$.

Region	a	b	c	d
		Odd-A nuclei		
I	−1.65948	−0.11308	−0.06898	0.02948
III	−0.8437	0.05854	−0.03726	0.0402
IV	0.51361	0.00585	0.01281	0.00585
		Doubly-odd nuclei		
I	−0.82097	−0.12653	−0.04695	−0.13455
III	−2.72853	−0.02778	−0.09794	−0.04321
IV	0.53443	−0.00317	0.01402	−0.00363

5. Our works

Case of odd-A nuclei α decay

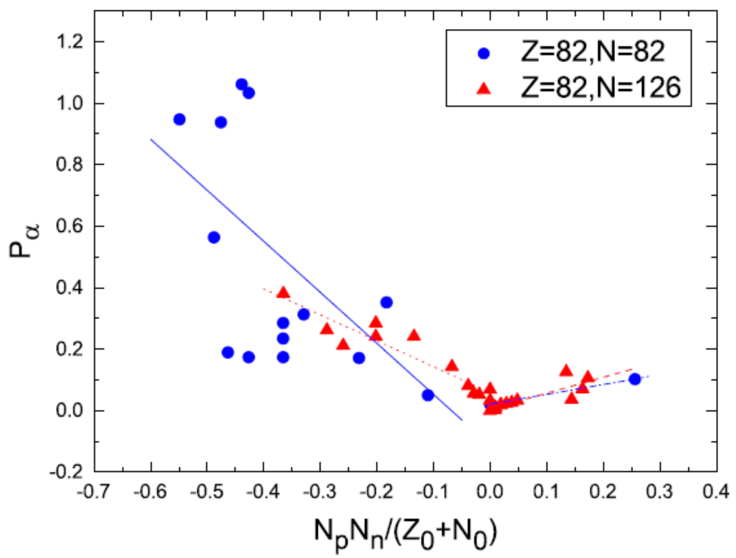


FIG. 2. The linear relationship between α preformation probabilities and $\frac{N_pN_n}{Z_0+N_0}$. N_p and N_n represent valence protons (holes) and neutrons (holes) of he parent nucleus, respectively. Z_0 and N_0 denote the magic numbers of the proton and neutron, respectively. The blue solid and dash-dotted lines denote the fittings of nuclei in regions I and, II, respectively. The red dotted and dashed lines represent the fittings of nuclei in regions III and IV, respectively.

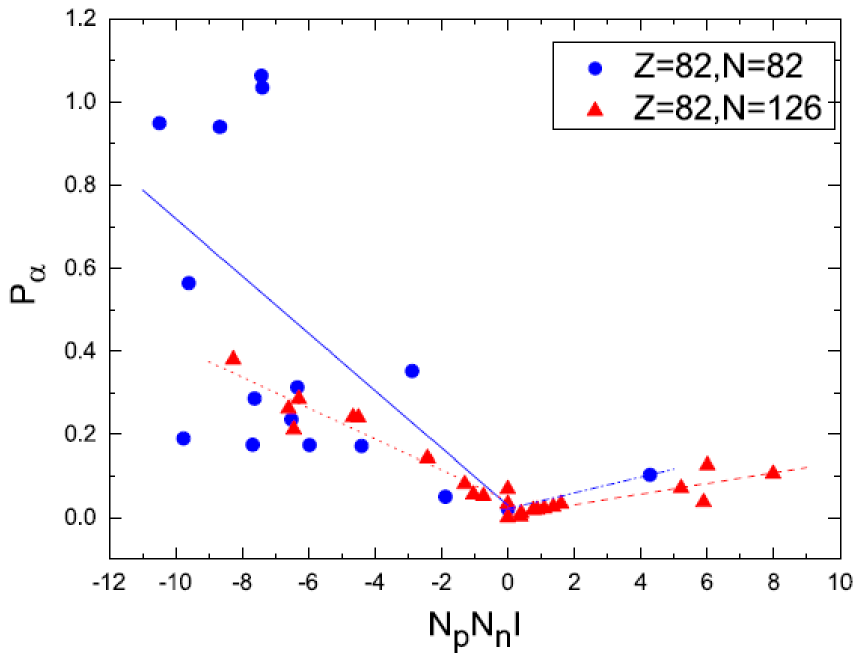


FIG. 3. The same as Fig. 2, but depicting the linear relationship between α preformation probabilities and the product of valence protons (holes), neutrons (holes), and isospin asymmetry as N_pN_nI.

5. Our works

Case of doubly odd nuclei α decay

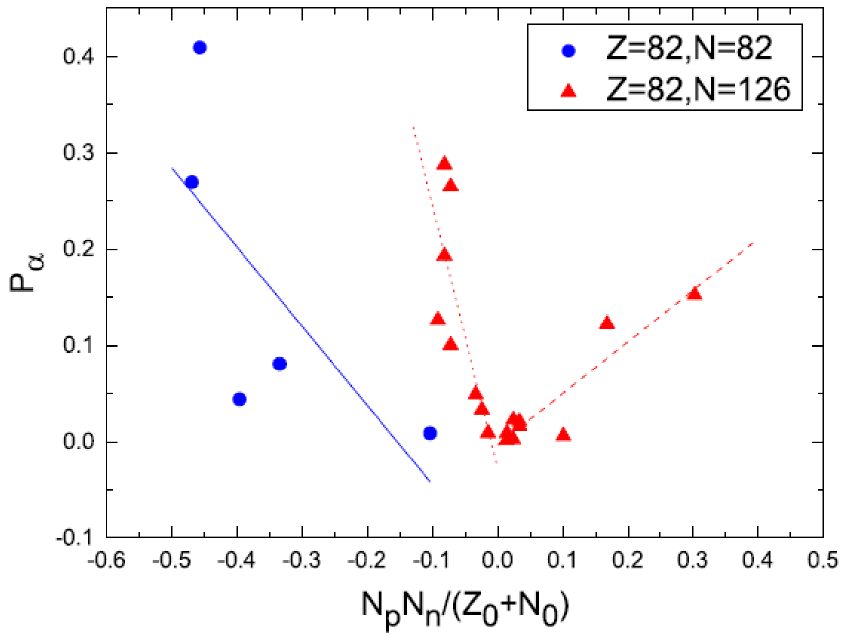


FIG. 4. The same as Fig. 2, but depicting doubly-odd nuclei in accordance with $\frac{N_pN_n}{Z_0+N_0}$.

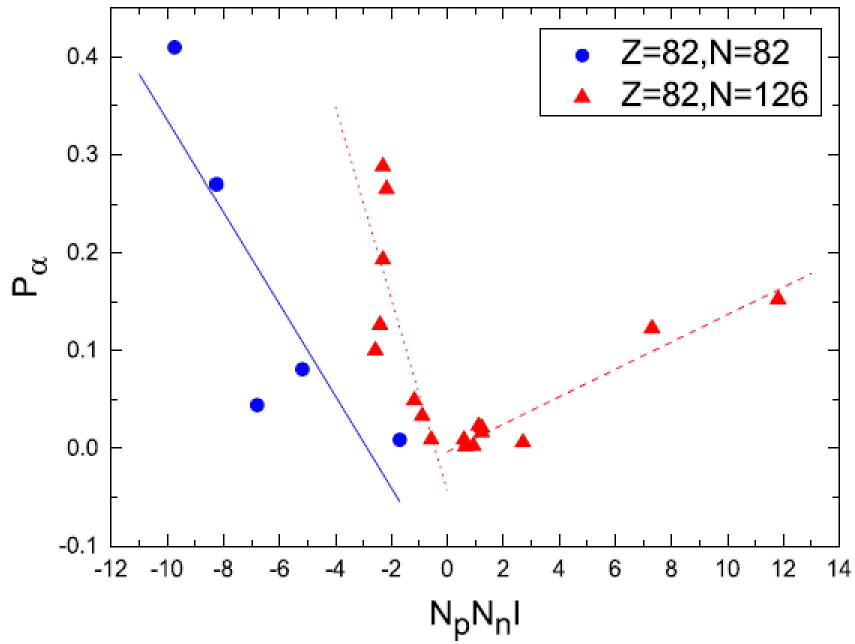


FIG. 5. The same as Fig. 2, but depicting doubly-odd nuclei in accordance with N_pN_nI.

5. Our works

I. Based on the (Cluster-formation model) CFM, **we study the α preformation factors** of nuclei around Z = 82,N = 126 closed shells.

II. **We systematically study the α decay half-lives** of nuclei around the Z = 82, N = 126 shell closures within the proximity potential 1977 formalism taking $\boldsymbol{P_\alpha}$ **= 1** and the **realistic** $\boldsymbol{P_\alpha}$ **evaluated by CFM**, respectively.

PHYSICAL REVIEW C **97**, 044322 (2018)

Systematic study of α decay of nuclei around the $Z = 82$, $N = 126$ shell closures within the cluster-formation model and proximity potential 1977 formalism

Jun-Gang Deng,[1] Jie-Cheng Zhao,[1] Peng-Cheng Chu,[2,*] and Xiao-Hua Li[1,3,4,†]
[1]*School of Nuclear Science and Technology, University of South China, 421001 Hengyang, People's Republic of China*
[2]*School of Science, Qingdao Technological University, 266000 Qingdao, People's Republic of China*
[3]*Cooperative Innovation Center for Nuclear Fuel Cycle Technology & Equipment, University of South China, 421001 Hengyang, People's Republic of China*
[4]*Key Laboratory of Low Dimensional Quantum Structures and Quantum Control, Hunan Normal University, 410081 Changsha, People's Republic of China*

(Received 2 February 2018; published 26 April 2018)

5. Our works

I. Based on the (Cluster-formation model) CFM, **we study the α preformation factors** of nuclei around *Z* = *82*, *N* = *126* closed shells.

Why do we select the CFM to calculate the P_α?

① It is a **simple**, **effective**, and **microscopic way**. Once the **binding energies** of parent nuclei and neighboring nuclei are known, one can easily evaluate the P_α.

② It is interesting to validate whether the **realistic P_α** within CFM is also linearly dependent on the product of valance protons (holes) and valance neutrons (holes) $N_p N_n$.

X.-D. Sun, P. Guo, and X.-H. Li, Phys. Rev. C **94**, 024338 (2016)

J.-G. Deng, J.-C. Zhao, D. Xiang, and X.-H. Li, Phys. Rev. C 96, 024318 (2017)

5. Our works

Case of even-even nuclei α decay

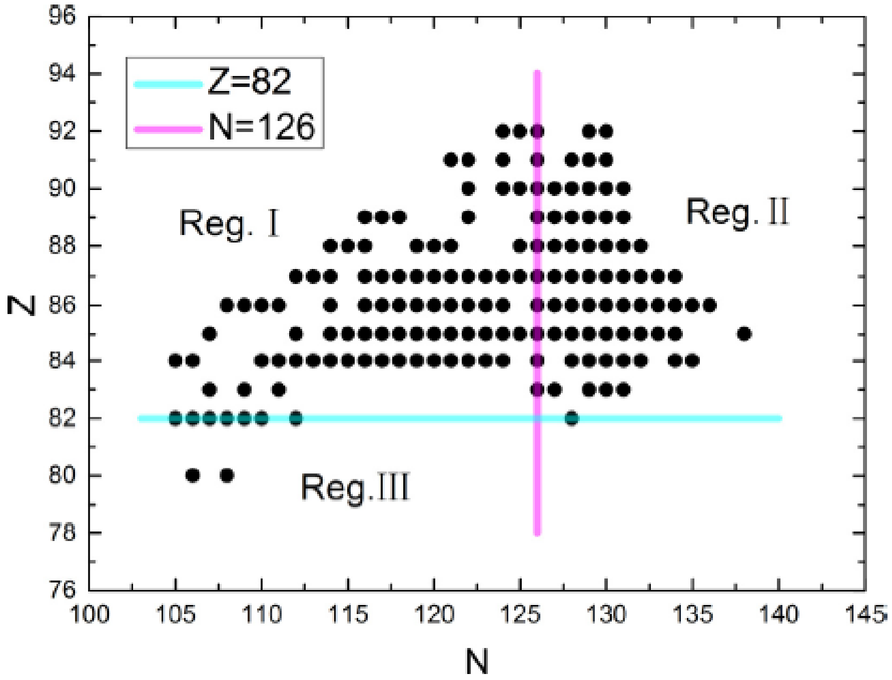


FIG. 1. Nuclide chart is divided into three regions. The cyan and magenta lines denote the $Z = 82$, $N = 126$ nuclear shell closures, respectively.

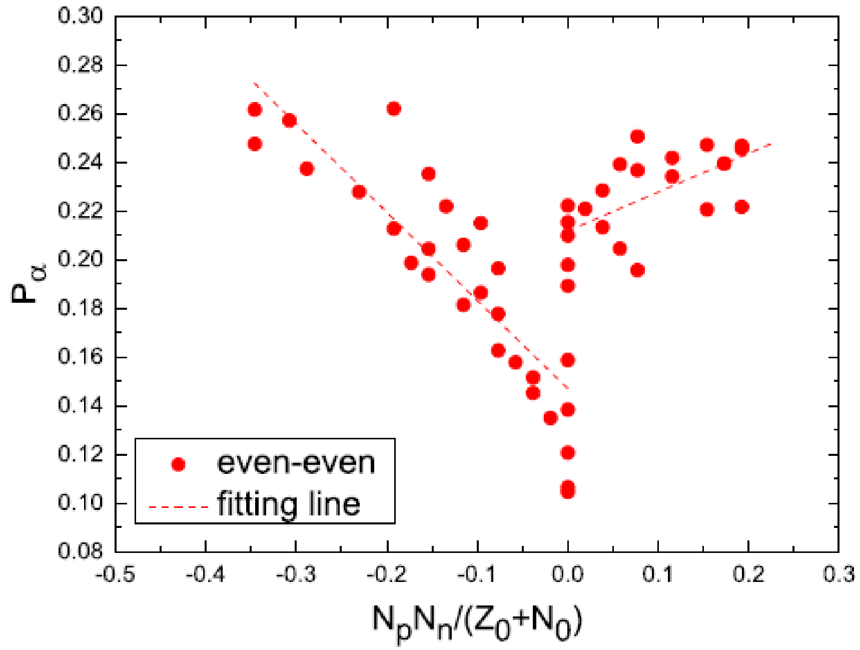


FIG. 2. The linear relationship between α preformation factors and $\frac{N_pN_n}{Z_0+N_0}$. N_p and N_n represent valence protons (holes) and neutrons (holes) of parent nucleus, respectively. Z_0 and N_0 mean the magic numbers of proton and neutron, respectively. The dash lines represent the fittings of α preformation factors.

5. Our works

Case of odd-A nuclei α decay

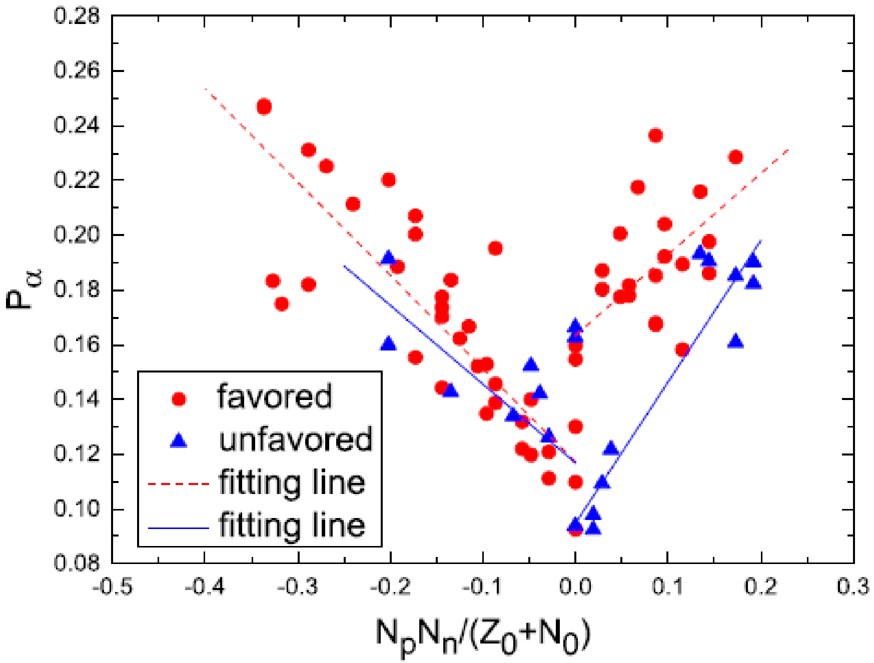


FIG. 3. Same as Fig. 2, but it depicts linear relationships between P_α and $\frac{N_p N_n}{Z_0+N_0}$ of odd-A nuclei. The red circle and blue triangle represent the cases of favored and unfavored α decay, respectively. The red dash and blue solid lines represent the fittings of α preformation factors for cases of favored and unfavored α decay, respectively.

Case of doubly odd nuclei α decay

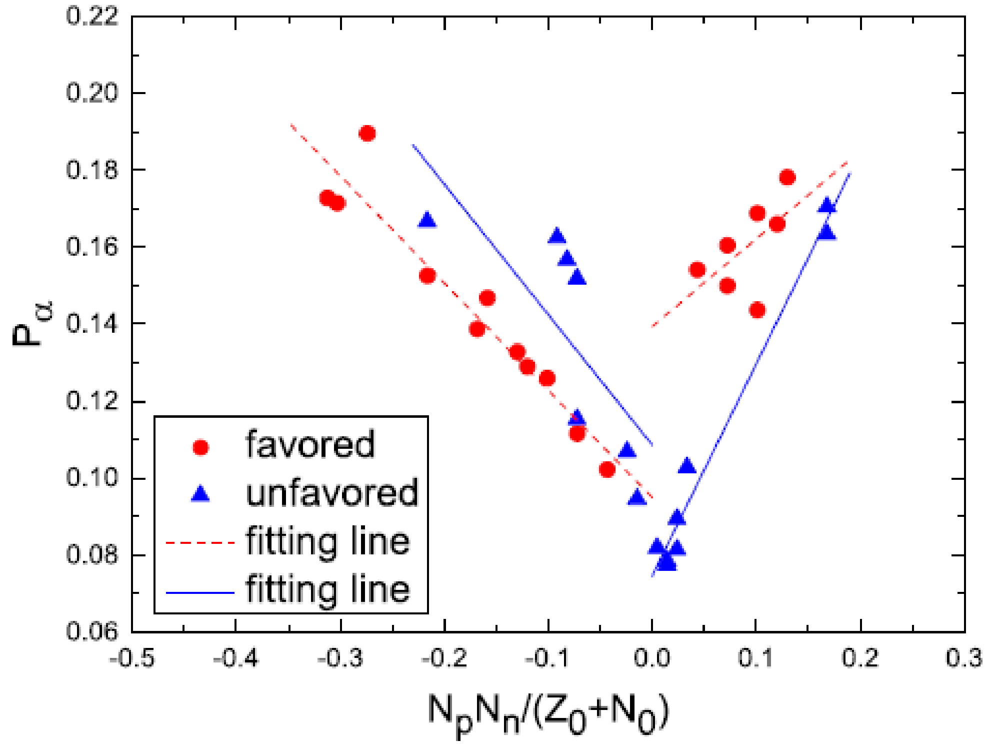


FIG. 4. Same as Figs. 2 and 3, but it depicts linear relationships between P_α and $\frac{N_p N_n}{Z_0+N_0}$ of doubly odd nuclei.

5. Our works

P_α is obtained by the CFM. **We find that the realistic P_α calculated by CFM** for nuclei around $Z = 82$, $N = 126$ shell closures **are linear with N_pN_n**.

$$P_\alpha = a\frac{N_pN_n}{Z_0 + N_0} + b$$

$Z_0 = 82$, $N_0 = 126$ represent the magic number of proton and neutron.

$$N_p = Z - Z_0,\ N_n = N - N_0$$

N_p is valance protons (holes)

N_n is valance neutrons (holes)

TABLE VI. The parameters of Eq. (21) that show α preformation factors are linearly related to N_pN_n.

Region	Favored decay		Unfavored decay	
	a	b	a	b
		Even-even nuclei		
I	−0.36222	0.14703		
II, III	0.15948	0.21175		
		Odd-A nuclei		
I	−0.34101	0.11712	−0.28777	0.11684
II, III	0.29582	0.16333	0.51621	0.09475
		Doubly odd nuclei		
I	−0.27858	0.09504	−0.33891	0.10868
II, III	0.22820	0.13944	0.55115	0.07457

南華大學
UNIVERSITY OF SOUTH CHINA

5. Our works

Case of odd-A nuclei α decay

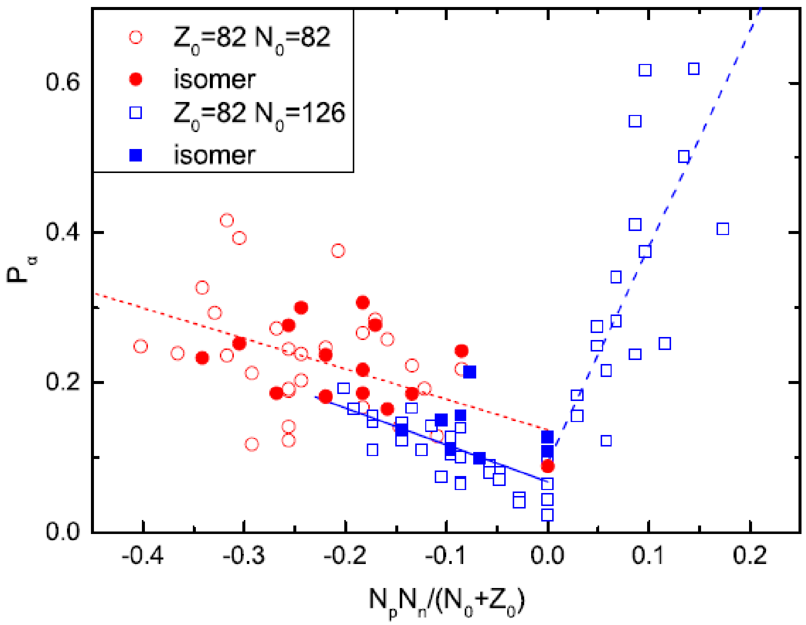


FIG. 3. The α preformation probabilities as a function of $\frac{N_p N_n}{N_0+Z_0}$, where N_p, N_n represent valence proton numbers and valence neutron numbers of the parent nucleus, respectively, and $N_0(Z_0)$ express neutron (proton) magic numbers. The blue dashed and solid lines denote the fit of nuclei in Regions IV and III, respectively. The red short dashed line denotes the fit of nuclei in Region I.

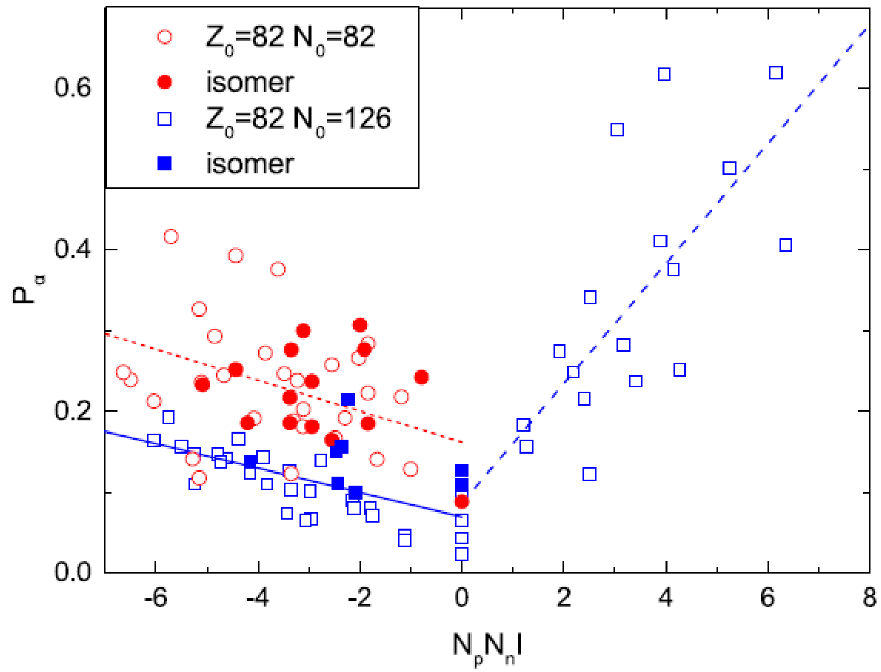


FIG. 4. Same as Fig. 3, but as a function of the product of valence proton numbers and valence neutron numbers and isospin asymmetry N_pN_nI.

南華大學
UNIVERSITY OF SOUTH CHINA

5. Our works

Case of doubly odd nuclei α decay

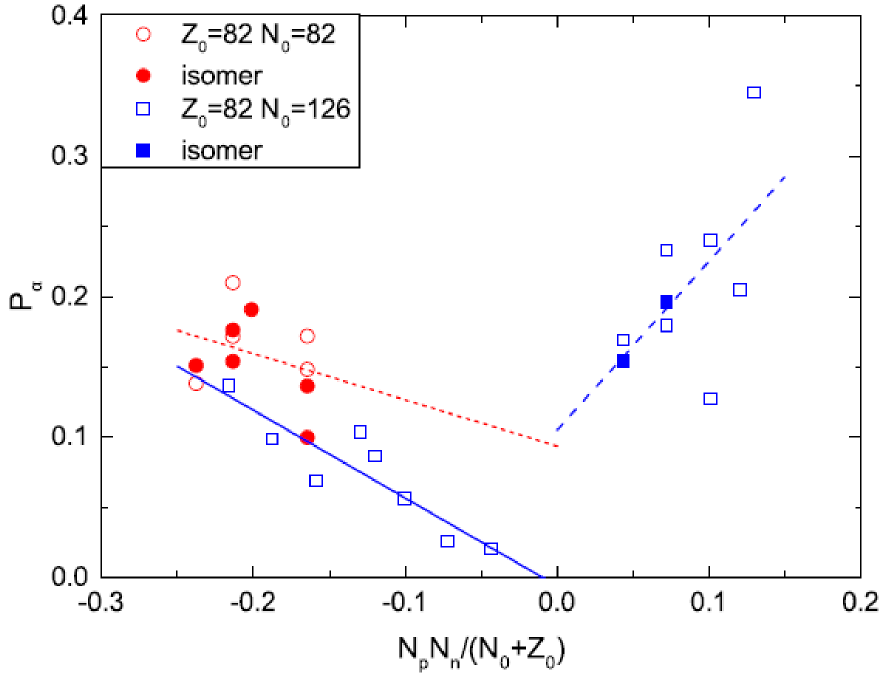


FIG. 5. Same as Fig. 3, but for doubly-odd nuclei as a function of $\frac{N_p N_n}{N_0+Z_0}$.

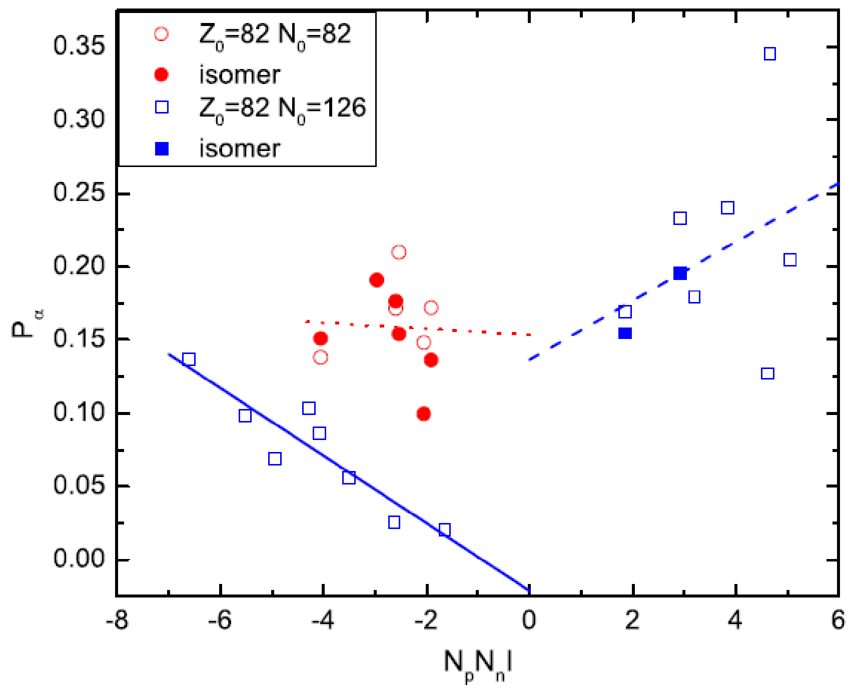


FIG. 6. Same as Fig. 3, but for doubly-odd nuclei as a function of $N_p N_n I$.

5. Our works

II. **We systematically study the α decay half-lives** of nuclei around the Z = 82, N = 126 shell closures within the proximity potential 1977 formalism taking $\boldsymbol{P_\alpha}$ **= 1** and the **realistic** $\boldsymbol{P_\alpha}$ evaluated by CFM, respectively.

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

$$\lambda = P_\alpha \nu P$$

In CPPM, the $\boldsymbol{P_\alpha}$ is left out of consideration or assumed as $\boldsymbol{P_\alpha}$= 1.

$$\lambda = \nu P$$

5. Our works

$T_{1/2}^{calc1}$, $T_{1/2}^{calc2}$ and $T_{1/2}^{calc3}$ denote calculated α decay half-life by proximity potential Prox.1977 formalism without considering P_α, with taking P_α by CFM, and with fitting P_α.

σ_1, σ_2, and σ_3 denote standard deviations between $T_{1/2}^{calc1}$, $T_{1/2}^{calc2}$, $T_{1/2}^{calc3}$ and $T_{1/2}^{expt}$, respectively.

$$\sigma = \sqrt{\sum\left(\log_{10} T_{1/2}^{calc} - \log_{10} T_{1/2}^{expt}\right)^2 \Big/ n}$$

TABLE VII. The standard deviations between α decay half-lives of calculations and experimental data.

Nuclei	Favored decay			Unfavored decay		
	σ_1	σ_2	σ_3	σ_1	σ_2	σ_3
Even-even nuclei	0.583	0.380	0.383			
Odd-*A* nuclei	0.659	0.370	0.366	0.897	0.542	0.536
Doubly odd nuclei	0.813	0.215	0.213	1.631	0.940	0.926

6.Summary

- **Conclusions:**

I. The P_α of nuclei around shell closures is linear with N_nN_p in all cases.

II. Our works show that the valance proton-neutron interaction plays a key role in the α preformation for nuclei around Z = 82,N = 126 shell closures whether the P_α is model dependent or microcosmic.

谢谢

南華大學
UNIVERSITY OF SOUTH CHINA

5. Our works

Systematic study of α decay of nuclei around $Z = 82$, $N = 126$ shell closure within a generalized liquid drop model

Hong-Ming Liu,[1] You-Tian Zou,[1] Xiao Pan,[1] Xiao-Jun Bao,[2,3,*] and Xiao-Hua Li[1,3,4,†]

[1] *School of Nuclear Science and Technology, University of South China, 421001 Hengyang, People's Republic of China*
[2] *Hunan Normal University, Changsha 410081, Peoples Republic of China*
[3] *Key Laboratory of Low Dimensional Quantum Structures and Quantum Control, Hunan Normal University, 410081 Changsha, People's Republic of China*
[4] *Cooperative Innovation Center for Nuclear Fuel Cycle Technology & Equipment, University of South China, 421001 Hengyang, People's Republic of China*

In this work, we systematically study the α decay preformation factors P_α and α decay half-lives of 152 nuclei around $Z = 82$, $N = 126$ closed shells based on a generalized liquid drop model while P_α is extracted from the ratio of the calculated α decay half-life to the experimental one. The results show that there is an obvious linear relationship between P_α and the product of valance protons (holes) and valance neutrons (holes) N_pN_n. Combining with our previous works [Sun *et al.*, Phys. Rev. C **94**, 024338 (2016); Deng *et al.*, ibid. **96**, 024318 (2017); Deng *et al.*, ibid. **97**, 044322 (2018)] and the work of Seif *et al* [Seif *et al.*, Phys. Rev. C **84**, 064608 (2011)], we suspect that this phenomenon of linear relationship for the nuclei around those closed shells is model independent. It confirms the importance of valence protons (holes) and valence neutrons (holes) in the formation of α clusters. Meanwhile, we use the fitted P_α obtained by fitting the calculated α decay half-lives to the experimental ones to calculate the α decay half-lives of these nuclei. The calculated results are agree with the experimental data well.

5. Our works

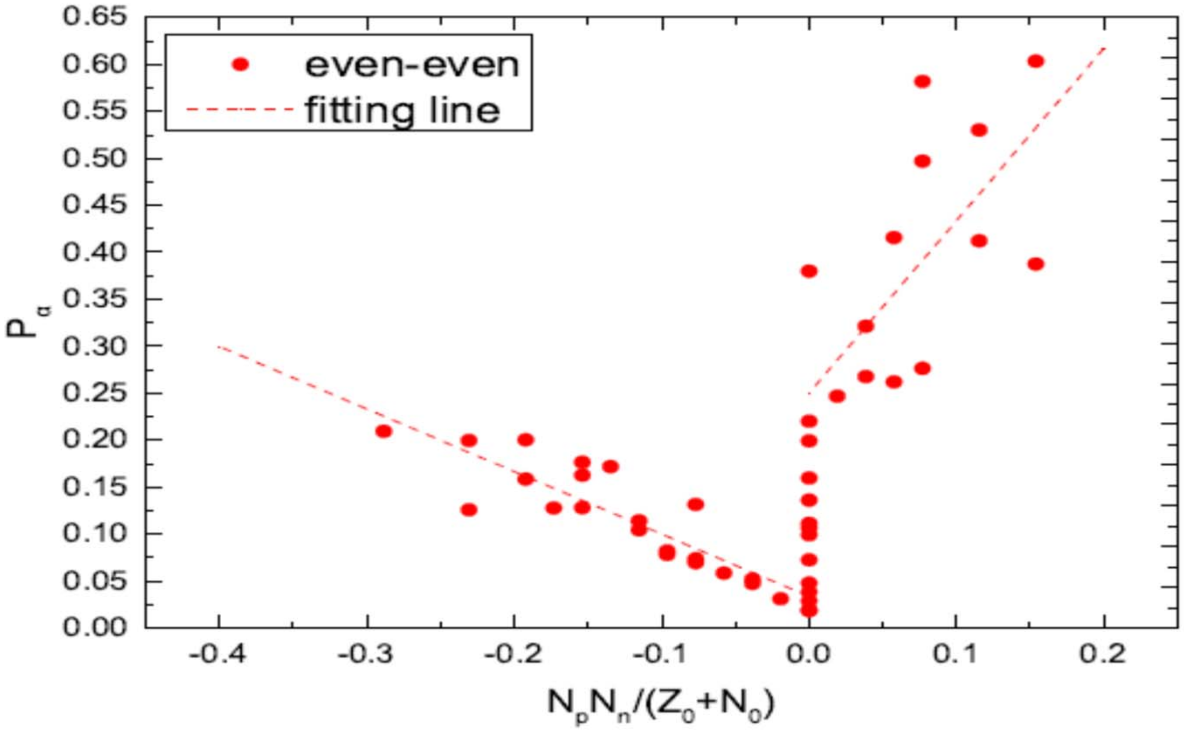


FIG. 1. (color online) The α preformation factors of even-even nuclei around $Z_0 = 82$ and $N_0 = 126$ shell closures as a function of $\frac{N_p N_n}{N_0+Z_0}$, where N_p and N_n denote valence protons (holes) and neutrons (holes) of parent nucleus, respectively. The dash lines are the fittings of α preformation factors.

南華大學
UNIVERSITY OF SOUTH CHINA

5. Our works

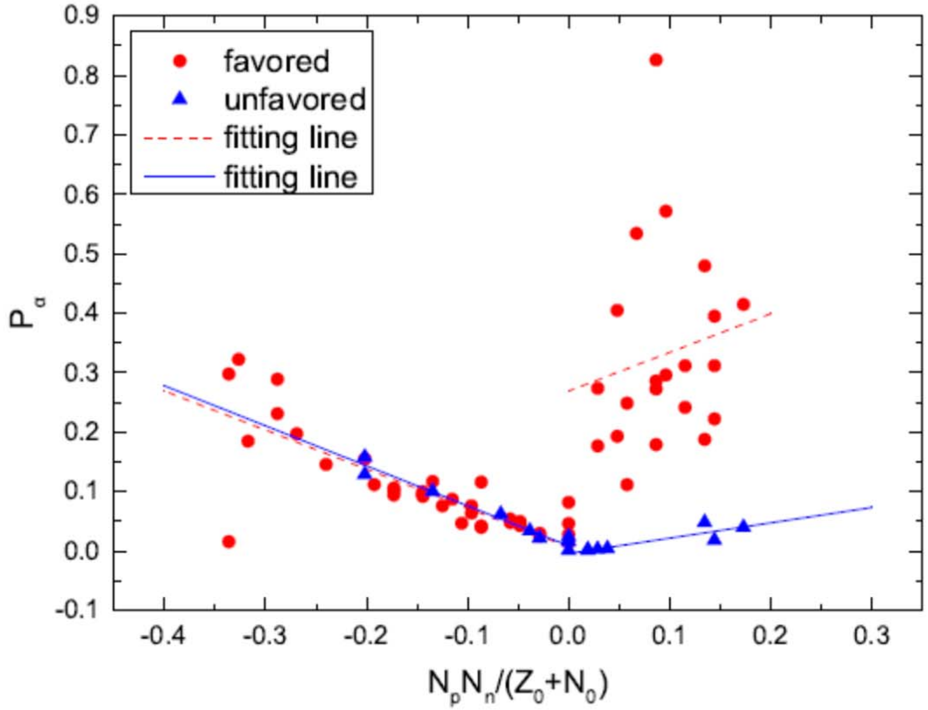


FIG. 2. (color online) Same as Fig. 1, but it represents the α preformation factors as a function of $\frac{N_pN_n}{N_0+Z_0}$ of odd-A nuclei.

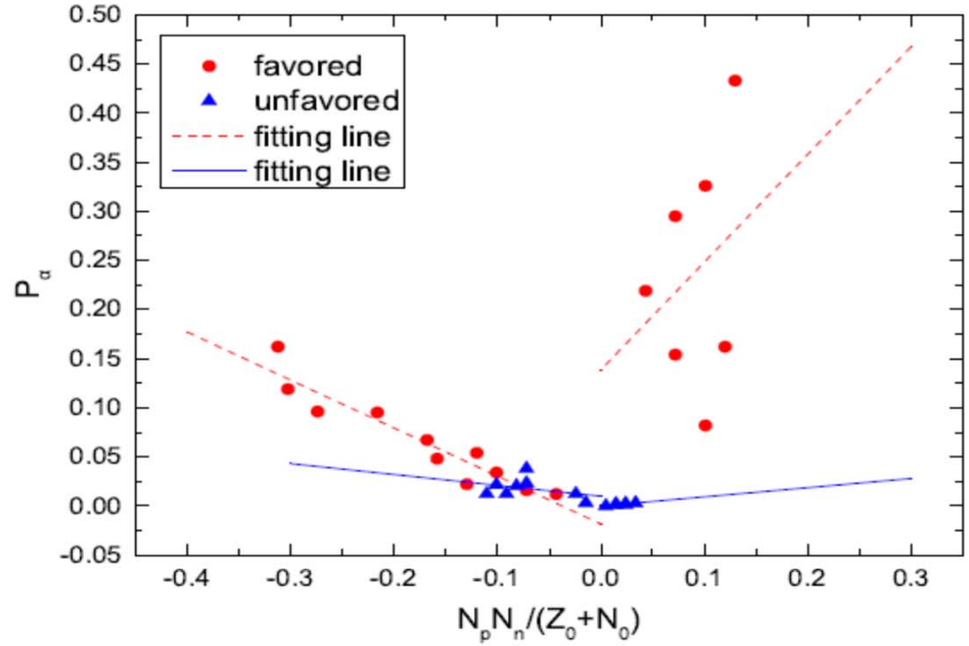


FIG. 3. (color online) Same as Fig. 1, but it represents the α preformation factors as a function of $\frac{N_pN_n}{N_0+Z_0}$ of doubly-odd nuclei.