Size Compression of Nucleon Pair On Nuclear Surface

Qing Zhao
Huzhou University

Collaborators: Bo Zhou (Fudan Univ.)

Masaaki Kimura (RIKEN)

Seung-heon Shin (Hokkaido Univ.)

Background

2p and 2n pair in experiments

2p pairing

PRL **99,** 022506 (2007) PHYSICAL REVIEW LETTERS week ending 13 JULY 2007

Coexistence of BCS- and BEC-Like Pair Structures in Halo Nuclei

K. Hagino,[1] H. Sagawa,[2] J. Carbonell,[3] and P. Schuck[4,5]
[1]*Department of Physics, Tohoku University, Sendai 980-8578, Japan*
[2]*Center for Mathematical Sciences, University of Aizu, Aizu-Wakamatsu, Fukushima 965-8560, Japan*
[3]*Laboratoire de Physique Subatomique et de Cosmologie, F-38026 Grenoble Cedex, France*
[4]*Institut de Physique Nucléaire, CNRS, UMR8608, Orsay F-91406, France*
[5]*Université Paris-Sud, Orsay F-91505, France*

(Received 17 November 2006; published 13 July 2007)

2n pairing

PHYSICAL REVIEW LETTERS **125,** 252501 (2020)

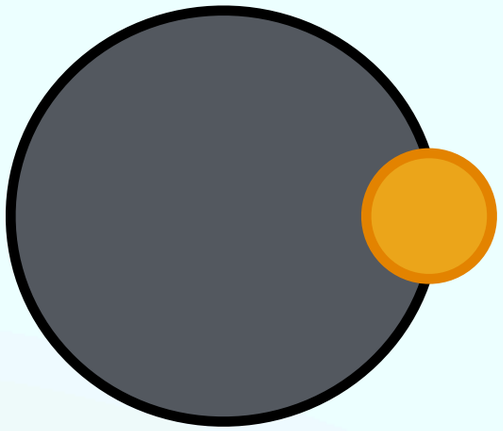
Surface Localization of the Dineutron in ^{11}Li

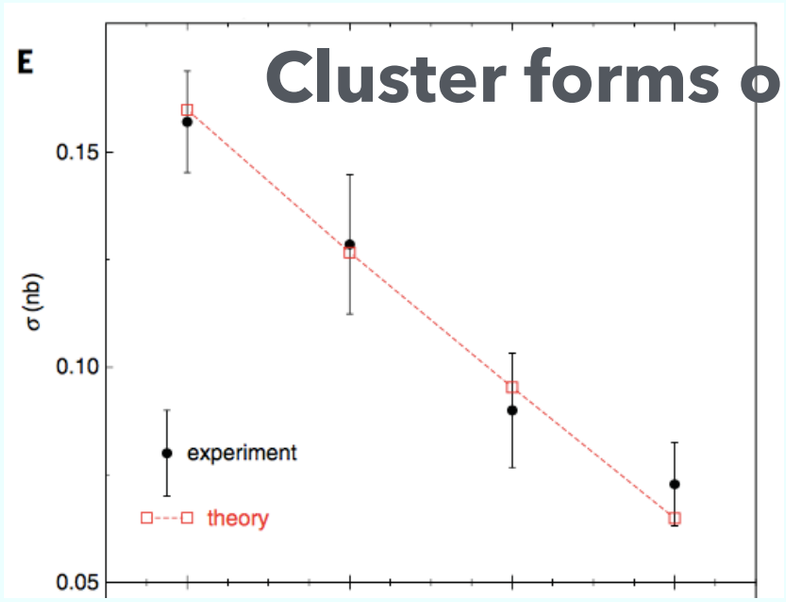
Y. Kubota,[1,2,*,§] A. Corsi,[3] G. Authelet,[3] H. Baba,[1] C. Caesar,[4] D. Calvet,[3] A. Delbart,[3] M. Dozono,[2] J. Feng,[5] F. Flavigny,[6,†] J.-M. Gheller,[3] J. Gibelin,[7] A. Giganon,[3] A. Gillibert,[3] K. Hasegawa,[8] T. Isobe,[1] Y. Kanaya,[9] S. Kawakami,[9] D. Kim,[14] Y. Kikuchi,[10,1,11] Y. Kiyokawa,[2] M. Kobayashi,[2] N. Kobayashi,[12] T. Kobayashi,[8] Y. Kondo,[13] Z. Korkulu,[14,15] S. Koyama,[12] V. Lapoux,[3] Y. Maeda,[9] F. M. Marqués,[7] T. Motobayashi,[1] T. Miyazaki,[12] T. Nakamura,[13] N. Nakatsuka,[16] Y. Nishio,[17] A. Obertelli,[3,*] K. Ogata,[18,11] A. Ohkura,[17] N. A. Orr,[7] S. Ota,[2] H. Otsu,[1] T. Ozaki,[13] V. Panin,[1] S. Paschalis,[4,‡] E. C. Pollacco,[3] S. Reichert,[19] J.-Y. Roussé,[3] A. T. Saito,[13] S. Sakaguchi,[17] M. Sako,[1] C. Santamaria,[3] M. Sasano,[1] H. Sato,[1] M. Shikata,[13] Y. Shimizu,[1] Y. Shindo,[17] L. Stuhl,[14,1] T. Sumikama,[8] Y. L. Sun,[3,*] M. Tabata,[17] Y. Togano,[13] J. Tsubota,[13] Z. H. Yang,[1] J. Yasuda,[17] K. Yoneda,[1] J. Zenihiro,[1] and T. Uesaka[1,20]

It has been reported that 2p and 2n can be formed as a nucleon-nucleon pair on the surface of the nuclei. **Even though they are unbound**.

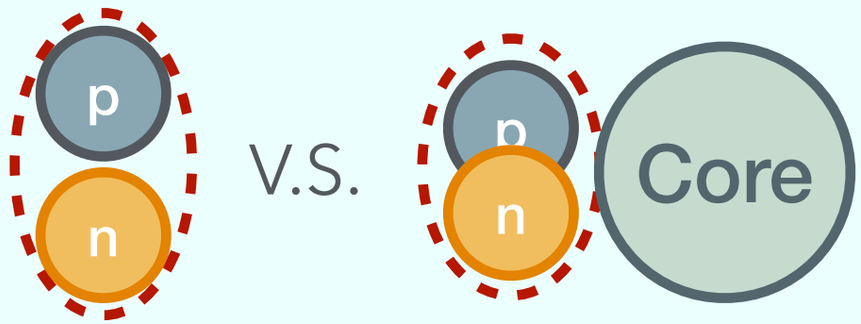
Background

Motivation



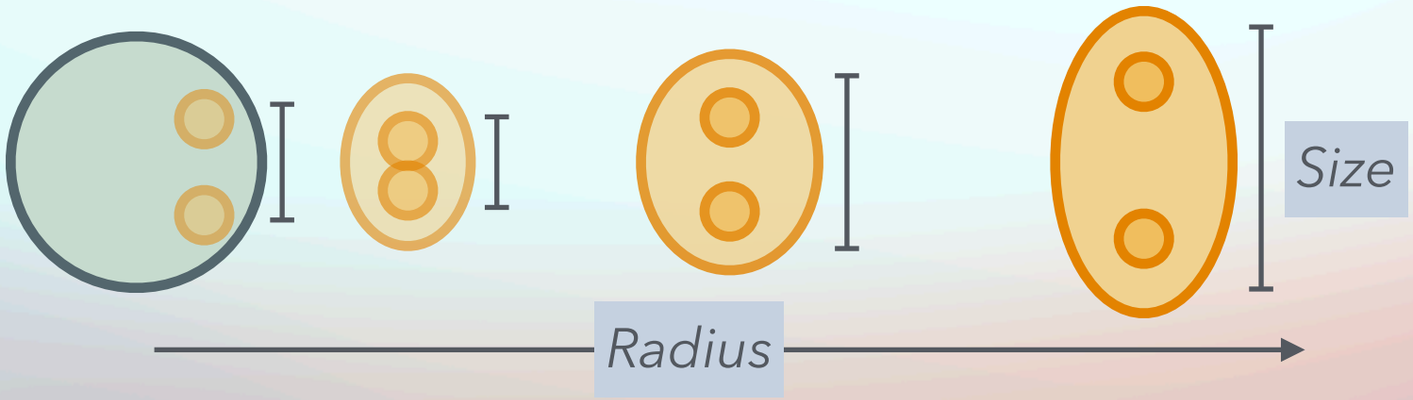


Cluster forms on the surface



J. Tanaka, Z. H. Yang et al, Science 371, 260 (2021)

Q: What is the role of the nuclear core on the pairing correlation?



This Work: We check the size changes of 2n, 2p, and 2d during their emission from the nuclei.

Framework

GCM and Reduced Width Amplitude (RWA)

We perform the Generator Coordinates Method (GCM) coupled with the cluster model to calculate the wave functions of the nuclei.

$$\phi(\mathrm{r}, Z) = (\frac{2\nu}{\pi})^{3/4}\exp[-\nu(\mathrm{r} - \frac{\mathrm{z}}{\sqrt{\nu}})^2 + \frac{1}{2}\mathrm{z}^2]\chi\tau \ ,$$

$$Z \equiv (\mathrm{z}, a, b) \ .$$

Total wave function:

$$\Psi^{J^\pi}_M = \sum_{i,K} f_{i,K}\hat{P}^{J^\pi}_{MK}\Phi_i$$

Basis wave function:

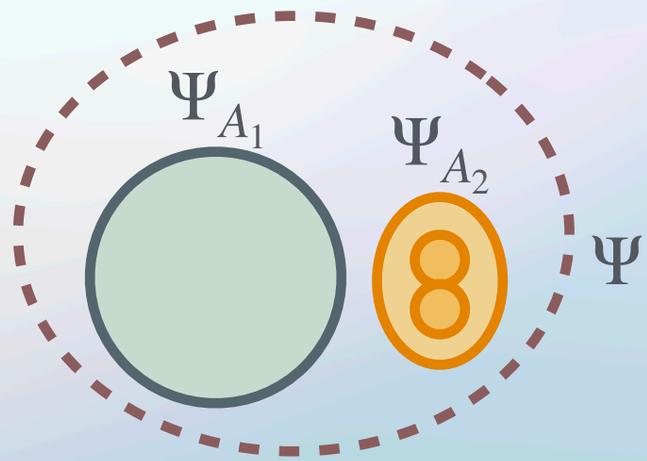
$$\Phi(\mathbf{z}_{\alpha_1} \dots Z_1, Z_2 \dots) = \mathscr{A}\{\Phi_\alpha(\mathbf{z}_{\alpha_1}) \dots \phi(Z_1)\phi(Z_2) \dots\}$$

Diagonalize them with Hamiltonian

The Reduced Width Amplitude (RWA) describes the wave function of a subsystem in the total nucleus.

RWA:

$$a y_l(a) = a\sqrt{\frac{A!}{(1+\delta_{A_1A_2})A_1!A_2!}}\langle\frac{\delta(r-a)}{r^2}\Psi_{A_1}\Psi_{A_2}Y_l(\hat{r})\,|\,\Psi\rangle$$



Framework

The average size of the di-nucleon

Wave function of di-nucleon:

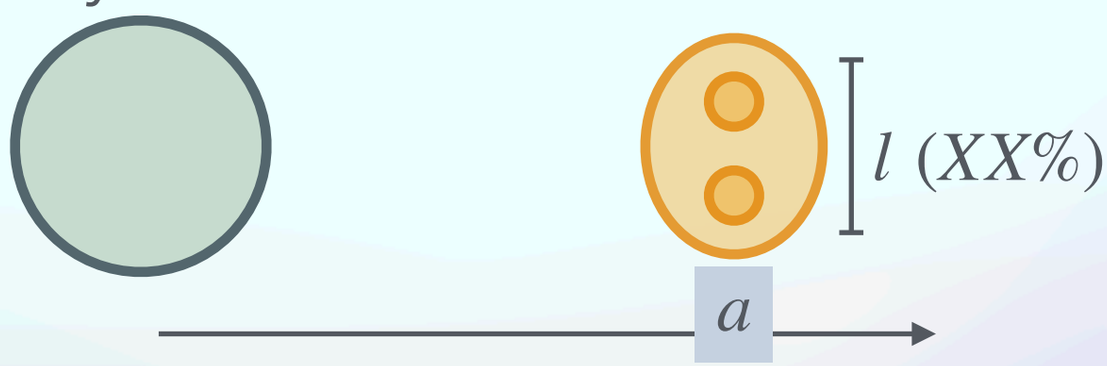
$$\Psi^{J^\pi=0^+} = \sum_K \hat{P}^{J^\pi}_{MK} \mathscr{A}\{\phi_1(s/2)\phi_2(-s/2)\}$$

The RWA becomes a two-dimensional wave function:

$$Y(r,s) = r y_l(r,s)$$

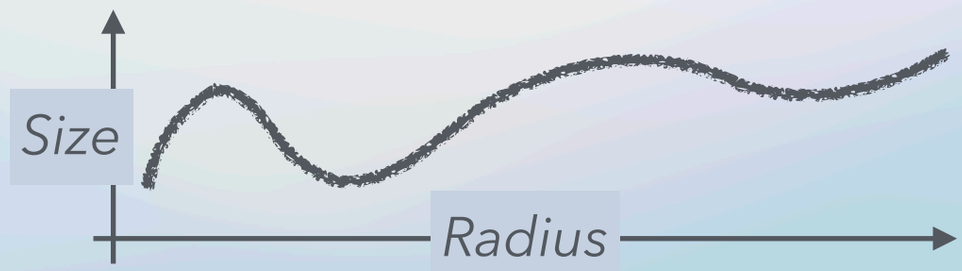
We can define the possibility density of a di-nucleon with size l at radius a:

$$P_a(l) = \frac{\int_a^{a+\delta a}\int_l^{l+\delta l} Y^2(r,s)drds}{\int_a^{a+\delta a}\int_0^{\infty} Y^2(r,s)drds}$$



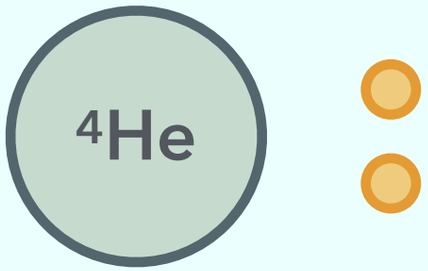
The average size of this di-nucleon can be valued as:

$$\bar{l}_a = \int_0^{\infty} l * P_a(l)dl$$

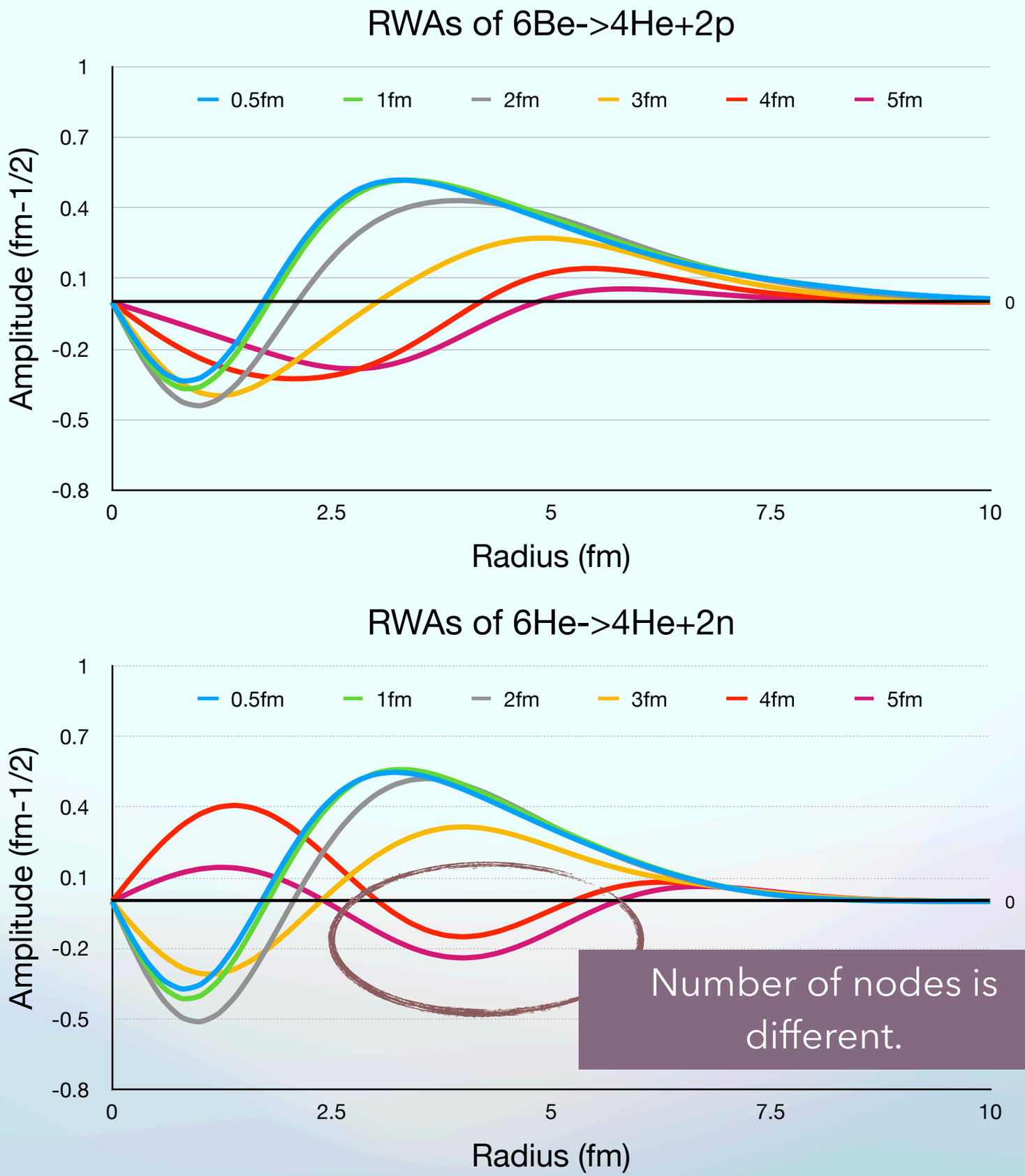


Results

2p and 2n

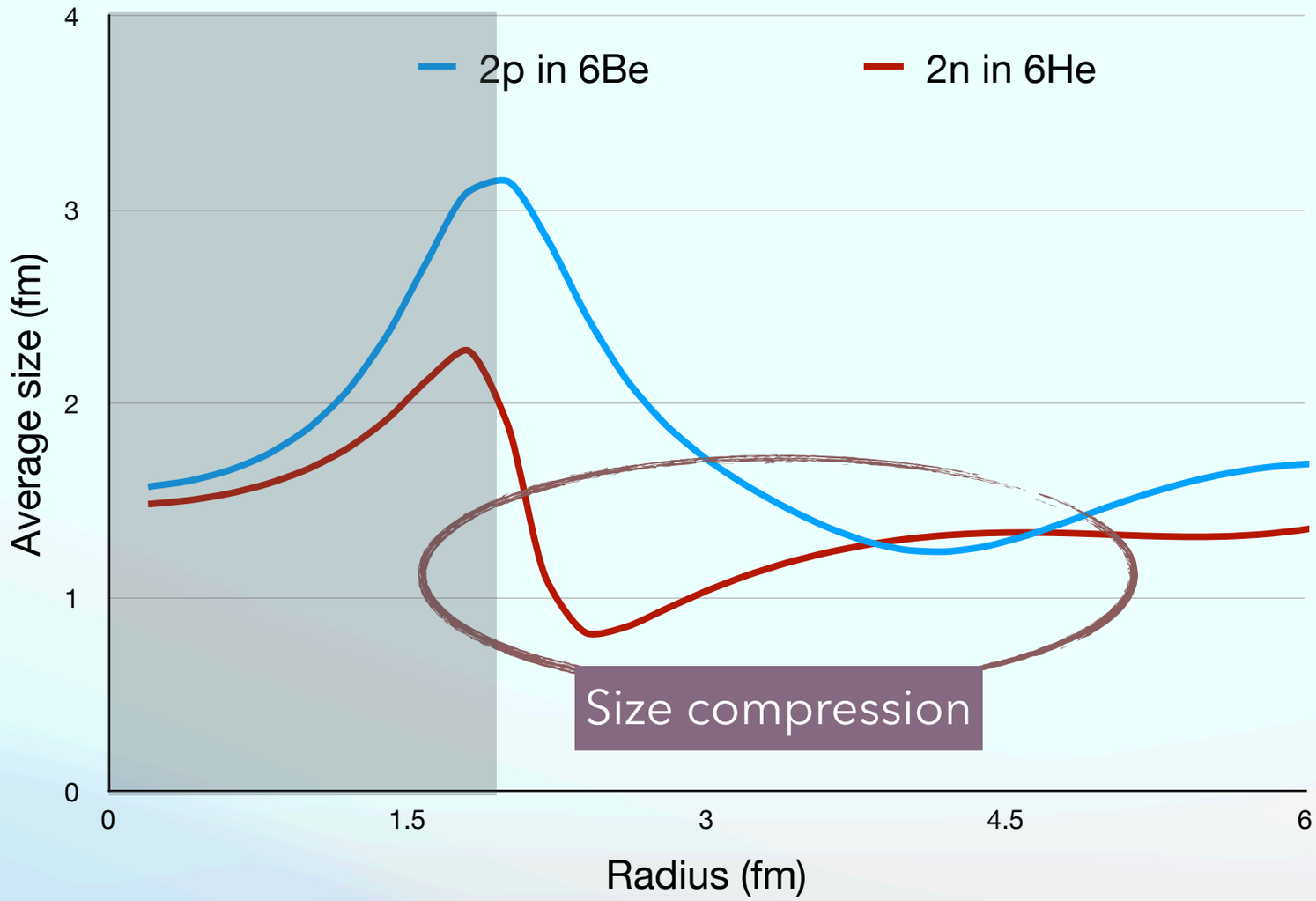


Number of the nodes relates to the orbital occupation (Quantum number).



Results

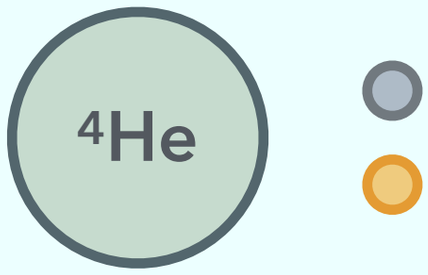
Average size

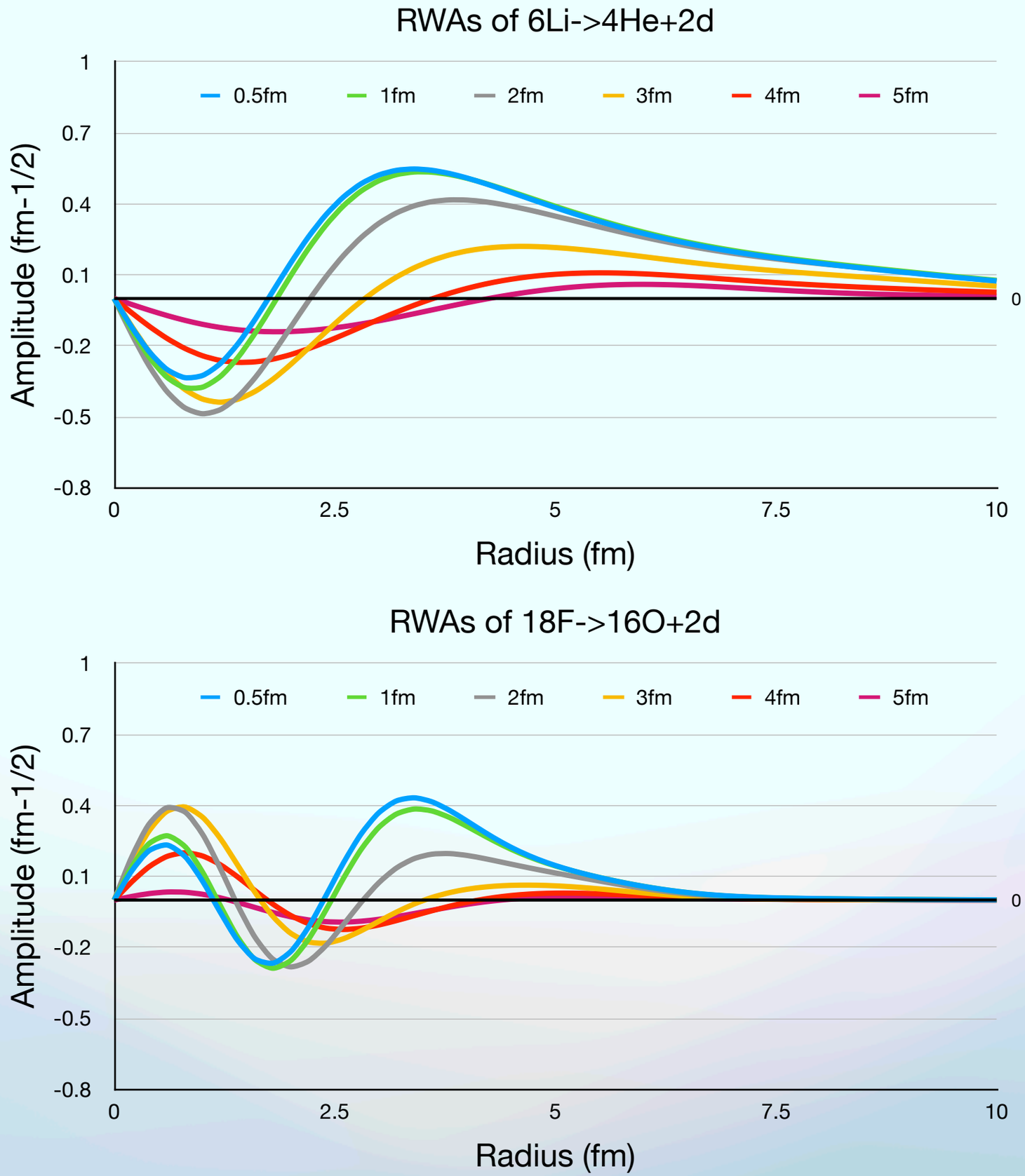


These results show the size compression of the 2p and 2n on the nuclear surface. They are consistent with the experiment observations.

Results

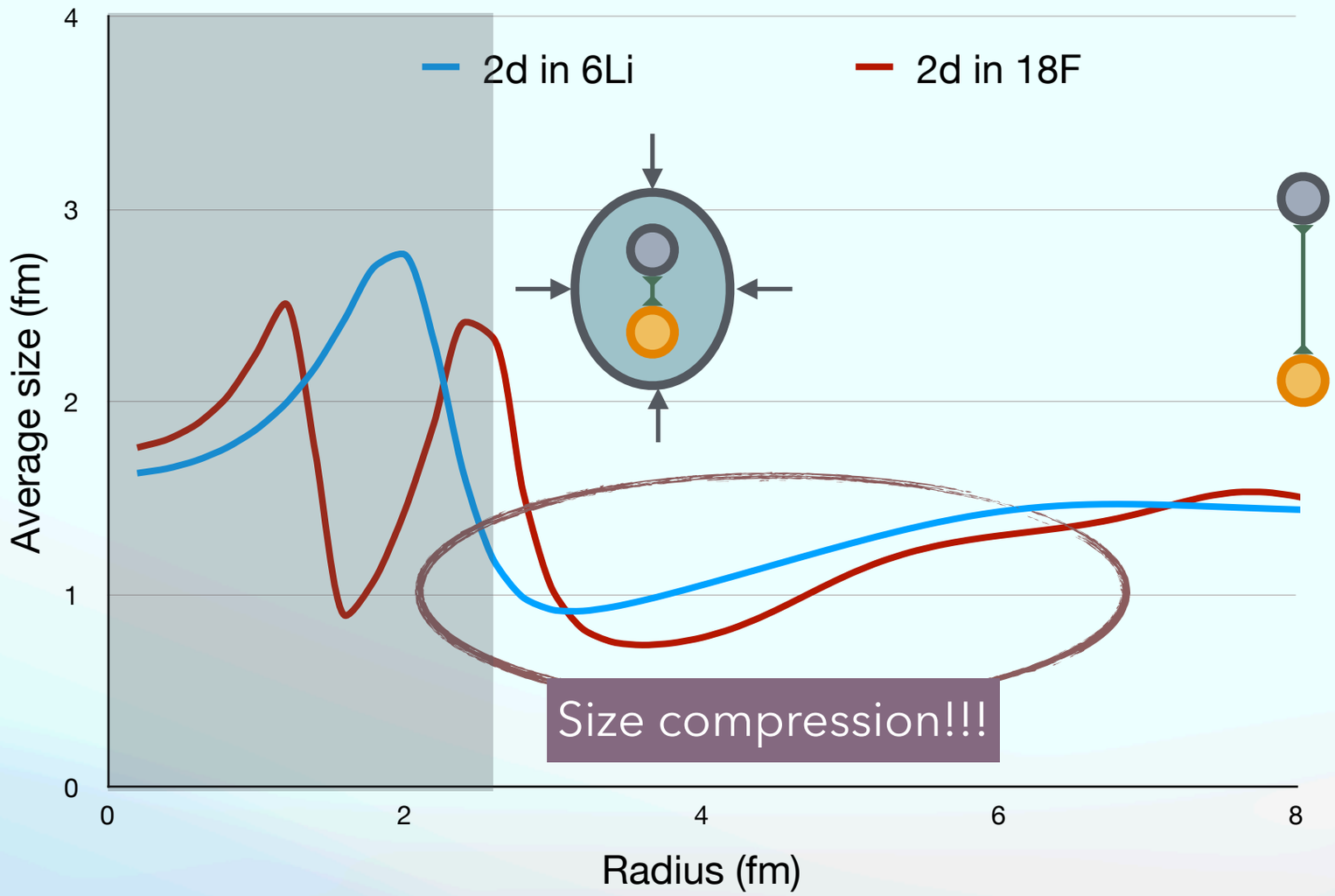
2d (Deuteron)





Results

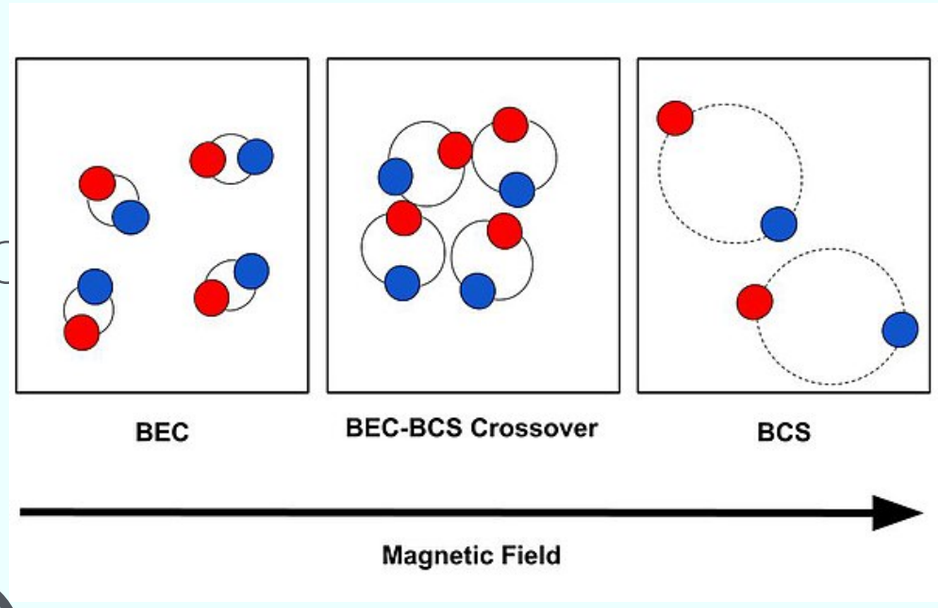
Average size of 2d(deuteron)

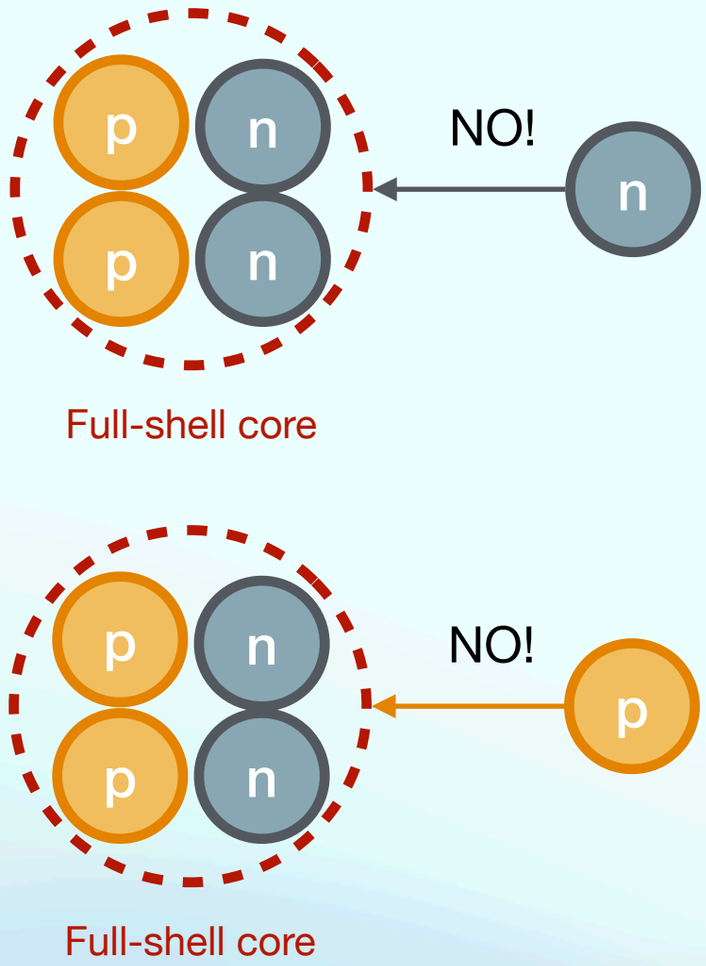


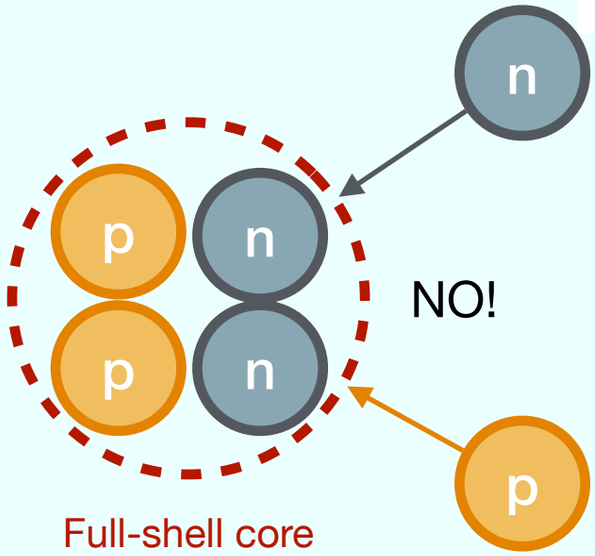
The size compression is obtained again for deuteron cases. This result suggests an additional pairing correlation from the nucleus core.

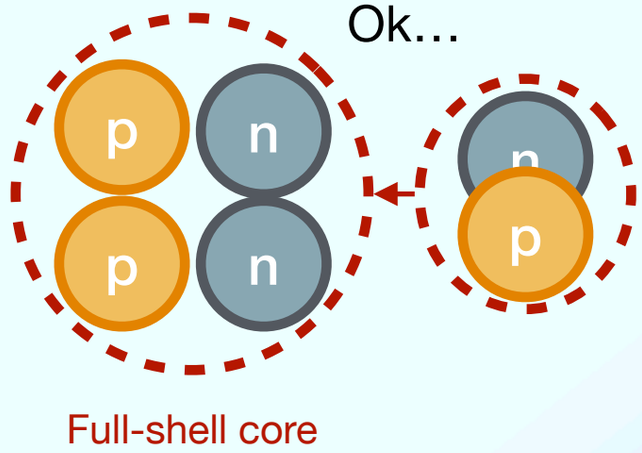
Results

Size compression and BCS-BEC crosso









Due to the Pauli blocking, the full-shell core prevents the valence nucleons from approaching. Only when these nucleons form as the Boson-like cluster, can they approach the surface region.

Conclusions

- We define the average size of a subsystem in the nucleus from its RWA and investigate the size changes of 2n, 2p, and 2d during their emission from the nuclei.

- All of these di-nucleons show the **size compression** on the surface of the nucleus, even for the boundary deuteron case.

- The further size compression of the deuteron-pair at the nucleus surface indicates an additional pairing effect from the nuclear core upon the nucleon pair.

- The conclusion made for this work may also be appropriate for the clustering effect.