Article ID: 1007－4627(2006)04－0427－04

Calculations of Relativistic Consistent Angular-momentum Projected Shell-model for Exotic Nuclei *

LI Yan-song[1, 2], F. H. AL-Khudair[2]

(1 *Center of Theoretical Nuclear Physics, National Laboratory of Heavy Ion Accelerator of Lanzhou, Lanzhou* 730000, *China*;
2 *Department of Physics, Tsinghua University, Beijing* 100084, *China*)

Abstract: The relativistic consistent angular-momentum projected shell-model (ReCAPS) developed recently is a self-consistent model and has stable parameters for various nuclei. The ReCAPS can describe the properties of known and unknown nuclei with stable deformations. In this paper, we present the calculations of several nuclei including normal stable nuclei, exotic nuclei and super heavy nuclei and compare the obtained results with experiment data.

Key words: relativistic consistent angular-momentum projected shell-model; relativistic mean field; angular momentum projection; exotic nuclei

CLC number: O571.41^{+}1　　**Document code**: A

1 Introduction

The ReCAPS was proposed in Refs. [1, 2]. In this paper, we just give the basic idea. The relativistic mean field (RMF)[3－5] model is a mean field model with interactions induced by exchanging mesons between nucleons. The RMF model can describe the properties of ground states of nuclei well. It can give proper binding energies, r. m. s radii, single nucleon orbits. It can also give spin-orbit coupling and deformations of nuclei automatically. The RMF has a self-consistent calculation and its parameters change little for different nuclei. It is believed to be a good model to study extreme nuclei, about which we know little. However the usual RMF calculation can not give information about excited states of nuclei. The ground states with deformations have not good angular momentum quantum numbers, either. The ReCAPS model combines the RMF model and the angular momentum projection (AMP) with appropriate assumption and approximation. It can describe both ground states and excited states of deformed nuclei well. The AMP approach was used in the projected shell model (PSM) at the earliest. This model was developed by K. Hara and Y. Sun, et al[6]. They applied the AMP approach in the well known Nilsson model. After AMP, the physical states with certain angular momentum numbers can be got from the Nilsson Hamiltonian and deformed wave functions. Because the PSM calculation is based on deformed wave functions, a small configuration space may be adopted and the calculation can be reduced greatly if proper deformation parameters are selected, while Shell Model has to take a huge amount of calculation in a very large configuration space. Small configuration spaces and calculations are the most remarkable advantages of the PSM. However, deformation parameters have to be given by hand. Because the RMF calculation can give the deformations auto-

* **Received date**: 20 Jul. 2006; **Revised date**: 26 Oct. 2006

Biography: Li Yan-song (1975－), male (Han Nationality), Jilin, Ph. D, working on structures and properties of nuclei; E-mail: ysli@mail.tsinghua.edu.cn

matically, the ReCAPS needs no deformation parameter and can provide abundant information about nuclei with unknown deformations, especially for exotic nuclei. Unlike the RMF, the ReCAPS can provide information about not only ground states, but also a great deal of rotated excited states. More information will be helpful to study exotic nuclei, because we can get more details about the structures of them through levels and electromagnetic transitions.

2 Results for Stable Nuclei ^{20}Ne, ^{170}Yb and ^{238}U

Calculations for various nuclei have shown that the ReCAPS can well describe the properties of even-even deformed nuclei from light to heavy nuclei. All the calculations used the same RMF parameters and only the strength of pairing needs to be adjusted slightly for different nuclei. As an example, the results of ^{20}Ne, ^{170}Yb and ^{238}U, which are deformed light, medium and heavy nuclei respectively, are shown . The energy levels and electromagnetic transitions B(E2) of the ground bands are shown in Figs. 1, 2 and 3. The comparisons between calculation and experiment[7] are given, too. The comparisons show that the calculated results agree with the experiment data very well. The calculations indicate that the calculated structures of the three nuclei are reliable and they have quadrupole deformations $\beta_2 = 0.54$, 0.31 and 0.29 respectively, which are given automatically in the calculations.

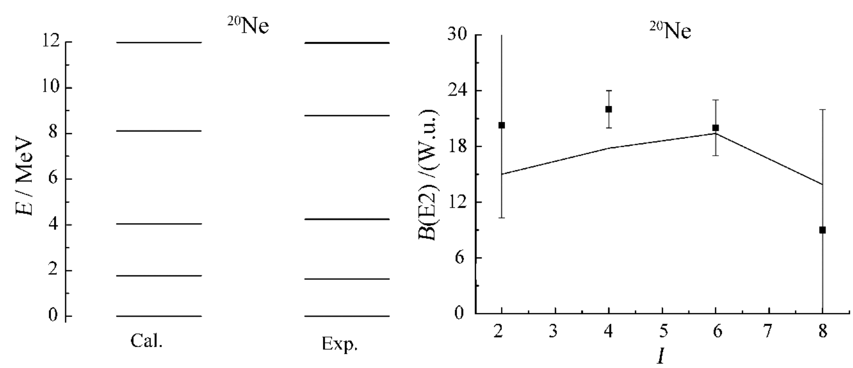

Fig. 1 The comparison between calculation and experiment for ^{20}Ne.

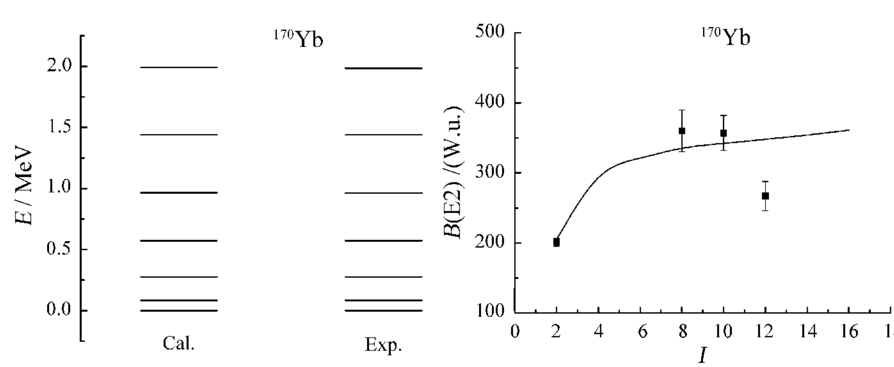

Fig. 2 The comparison between calculation and experiment for ^{170}Yb.

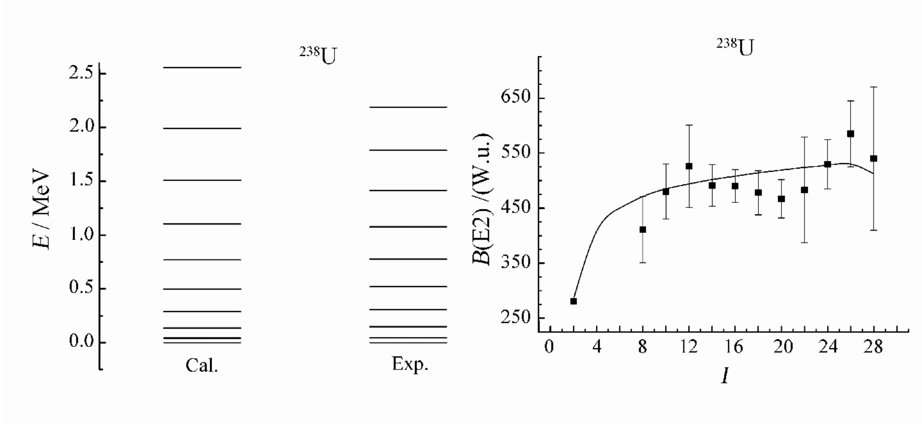

Fig. 3　The comparison between calculation and experiment for ^{238}U.

3　Predictions for Nuclei Far from the Stability Line

The ReCAPS uses the stable parameters in the model, and thus it has predicting power. For this purpose, ^{18}Be and super heavy nuclei ^{278}112 and ^{290}114 are calculated and the results are shown in Figs. 4, 5 and 6. We have known little at present experimentally about the three nuclei because they are all exotic nuclei far from β stable line and are very unstable. The ReCAPS result shows that they have deformations with $\beta_2 = 0.54, 0.17$ and 0.11 respectively. Some low-lying energy levels and transitions are shown in the figures, too. Band

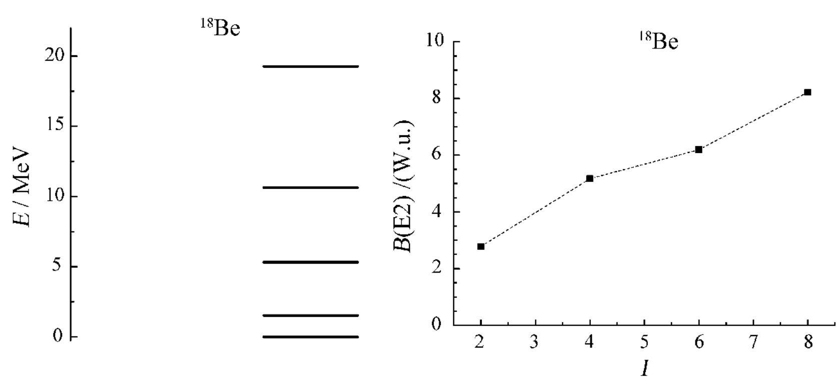

Fig. 4　The calculated levels and transitions of ^{18}Be.

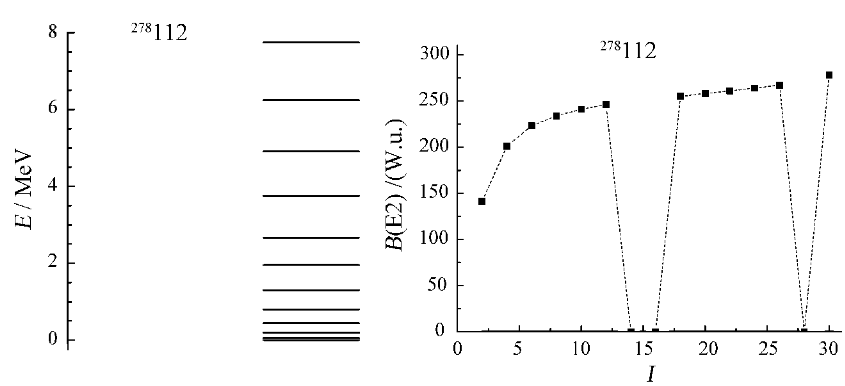

Fig. 5　The calculated levels and transitions of the nuclide ^{278}112.

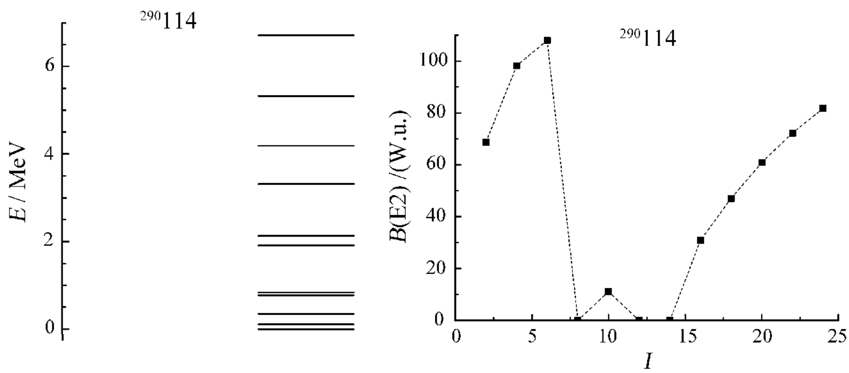

Fig. 6　The calculated levels and transitions of the nuclide $^{290}114$.

crossing and band bending can even be found through the transition data in the two super heavy nuclei. These nuclei may be obtained at an excited states experimentally. It will be interesting to test these calculations experimentally.

Acknowledgements　Thank Prof. Long Guilu for helpful discussions. Financial support from the center of Theoretical Nuclear Physics, National Laboratory of Heavy Ion Accelerator of Lanzhou is gratefully acknowledged.

References:

[1]　Li Y S, Long G L. Commun Theor Phys, 2004, **41**: 429.

[2]　Li Y S, Long G L. Commun Theor Phys, 2004, **41**: 579.

[3]　Gambhir Y K, Ring P, Thimet A. Ann Phys, 1990, **198**: 132.

[4]　Ring P, Stoitsov M V, Sharma M M. Phys Rev, 1994, **C50**: 1 445.

[5]　Behnsch R, Pöschl W, Vretenar D, *et al*. Nucl Phys, 1997, **A621**: 853.

[6]　Hara K, Sun Y. Int J Mod Phys, 1995, **E4**: 637.

[7]　Firestone R B. Table of Isotopes CD-ROM, WILK-INTERSCIENCE, 8th edtion, 1996.

关于极端原子核的相对论自洽角动量投影壳模型计算

李岩松[1,2]，F. H. AL-Khudair[2]

（1 兰州重离子加速器国家实验室原子核理论中心，甘肃 兰州 730000；

2 清华大学物理系，北京 100084）

摘　要：相对论自洽角动量投影壳模型是最近发展出来的一个自洽模型，它对于不同核区具有稳定的参数，能够很好地描述已知和未知具有稳定形变的各种原子核的性质。计算了若干包括稳定核素、极端核素和超重核素，并把计算结果与现有的实验数据进行了比较。

关 键 词：相对论自洽角动量投影壳模型；相对论平均场；角动量投影；极端原子核