The role of pions on nuclei based on the charge and parity projected chiral mean field model

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We study the role of pions on the ground states of finite nuclei with explicit treatment of pions by variation after charge and parity projection based on the relativistic chiral mean field (CPPCMF) model. We start from the linear sigma model Lagrangian, since we study the role of pions on the structure of nuclei from a point of veiw of the mass generation by spontaneous chiral symmetry breaking. This CPPCMF model has been applied to ^{4}He and demonstrated to provide good ground state properties within a spherical pion field ansazt[1].

We further apply this model to $N = Z$ even-even heavier nuclei up to ^{56}Ni. We find that pions play dominant role also for properties of ^{12}C. The pionic energy contribution to the total binding energy is about 50 % of net two-body attractive force. This amount is almost the same as case of ^{4}He. All nucleons participate in the pionic correlations for these nuclei. On the other hand, this pionic effect is significantly suppressed in ^{16}O due to the Pauli blocking effect. As comparison we take a configuration, $(0s_{1/2})^4(0p_{3/2})^8(0d_{5/2})^4$, where the blocked-effect dose not work. The amount of the pionic contribution is the same as cases of ^{4}He and ^{12}C in this configuration. We obtain an important consequence here. The pionic correlations depend strongly on the particle configurations in the shell structure within the spherical pion field ansatz. If there are no blocked-states the pionic contribution per particle is volumelike. This pattern is important to understand the manner of the pionic correlations for heavier systems within the spehrical ansatz.

For heavier nuclei, the pionic energy systematics as a function of nuclear mass number are clearly separated into two groups, the LS and jj closed-shell nuclei as shown in Fig.1. The large amount of pionic contributions are obtained for jj closed-shell nuclei as compared with those for LS closed-shell nuclei. The pionic energy difference between two groups of LS and jj closed-shell nuclei comes from pionic correlations by nucleons stay in the Fermi level of jj close-shell nuclei. Another important consequence obtained here is that this energy defference may indicate that the pion plays an important role on the formation of the jj magic numbers. The pionic contributions are reduced approximately as $A^{-2/3}$ with the nuclear mass number. We descibed the nature of high momentum components in the wave functions, which is typical character of pionic correlations, by using the CPPCMF method. This reduction of the pionic contribution, however, indicates necessity of further considerations about pseudoscalar nature of pions so as to account for the full strenght of pionic correlations according to comparing with other works[2, 3, 4].

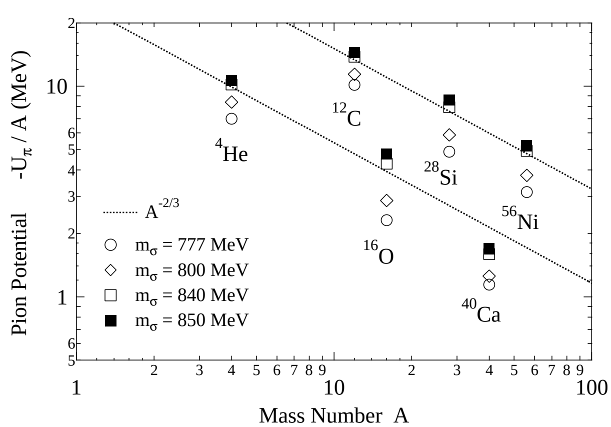

Figure 1: The pion energy per particle as a function of nuclear mass number. We adjusted the repulsive force by varying omega-nucleon coupling constant so as to reproduce the empirical binding energy for each sigma meson mass.

References

[1] Y. Ogawa, H. Toki, S. Tamenaga, S. Sugimoto, and K. Ikeda, Phys. Rev. **C73**, 034301(2006).

[2] N. Kaiser, S. Fritsch, W. Weise, Nucl. Phys. **A697**, 255(2002).

[3] R. B. Wiringa, S. C. Pieper, J. Carlson, and V. R. Pandharipande, Phys. Rev. **C62**, 014001(2000); S. C. Pieper and R. B. Wiringa, Annu. Rev. Nucl. Part. Sci. **51**, 53(2001).

[4] T. Myo, S. Sugimoto, K. Katō, H. Toki, and K. Ikeda, Prog. Theor. Phys. **117**, 257(2007).