Relativistic chiral mean field model with high-spin pion field for finite nuclei

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We study the property of nuclear system in the same footing as hadron physics starting with the linear σ model by Gell-Mann and Levy. The pion field appears symmetrically with the σ meson in this Lagrangian. For this purpose, we have constructed a relativistic framework, charge and parity projected chiral mean field model (CPPCMF), which can describe many-body correlations from pion-exchange interaction explicitly and can be applied to heavier nuclei.[1]. Our framework is, however, still within the spherical pion field ansatz. In this ansatz, one particle and one hole states, $|p-h; JM\rangle$, couple to $J^\pi = 0^-$. We then improve our framework so as to make it easy to use higher partial wave states of pion field, which correspond to the states of $J^\pi = 1^+, 2^-, 3^+$, ... so on. Inclusion of these higher partial wave states of pion provides an effect on nuclear bulk property[2]. We have to confirm the validity of pion's role on the formation of jj-magic structure[1] in the case of taking full strength of pionic correlations. This is because the 2p-2h corrections play major role on the production of strong attraction even in the nuclear matter and lead to the saturation property[2].

We construct a nuclear ground state wave function besed on the relativistic mean field basis as follows,

$$|\Psi\rangle = a_0|\Phi_0; 0\text{p}-0\text{h}\rangle + \sum_\alpha a_\alpha|\Phi_\alpha; 2\text{p}-2\text{h}\rangle, \tag{1}$$

where α represents the index of the 2p-2h channels and set a_α is decided by making the total energy, $E = \langle\Psi|\hat{H}|\Psi\rangle$, minimized. The matrix element of pion-exchange interaction between 0p-0h and 2p-2h, $\langle 2p-2h|\hat{H}_\pi|0p-0h\rangle$, is calculated by referring to the method of Appendix C in Ref.[3]. The energy contribution from this matrix element is large, and therefore perturbative treatment is not suitable for this problem. Simultaneously, σ and ω meson field are obtained by solving the minimization condition, $\partial E/\partial\phi = 0$, where ϕ represents σ or ω. The pionic correlations affect σ and ω meson fields through the scalar and vector densities, respectively,

$$\langle\Psi| : \bar{\psi}\Gamma\psi : |\Psi\rangle, \tag{2}$$

where Γ represents 1 or γ_0 for σ or ω meson, respectively. The variation with respect to a_α, σ, and ω meson field provides coupled equations. They are solved self-consistently.

We show the preliminary stages of our calculation for ^{4}He with respect to J^π in Fig. 1. The momentum-cutoff in the form factor is set to be 1 GeV. The pionic central part, $\vec{\sigma}_i \cdot \vec{\sigma}_j \vec{\tau}_i \cdot \vec{\tau}_j$, needs further the inclusion of the short range repulsion of the nuclear force[4].

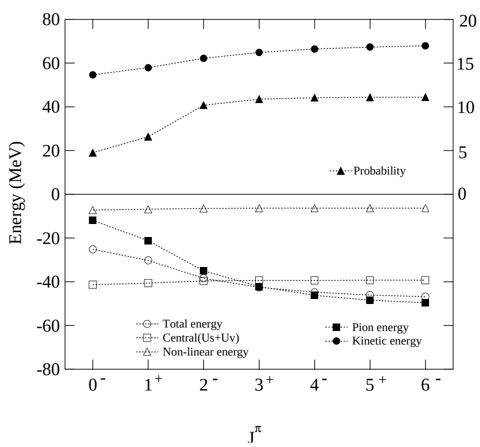

Figure 1: Energy convergence of various components as function J^π for ^{4}He.

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