Parity Projected relativistic Hartree scheme with the pion mean field model for finite nuclei

Y. Ogawa[1], H. Toki[1], S. Tamenaga[1],
S. Sugimoto[2], and K. Ikeda[2]
[1] *Research Center for Nuclear Physics (RCNP), Osaka University, Ibaraki, Osaka 567-0047, Japan*
[2] *Institute for Chemical and Physical Research (RIKEN), Wako, Saitama 351-0198, Japan*

We study the role of the pion on the properties of finite nuclei using the chiral sigma model in the framework of relativistic mean field theory[1]. The background of which we use in this model is that the nucleon obtains a mass by the spontaneous chiral symmetry breaking and simultaneously pion mode appears. The pion mean field breaks the parity symmetry of the intrinsic state. It is necessary to restore the parity symmetry of the total wave function, because the nucleus ground state has a definite parity. We employ the parity projected wave function $\Psi^{\pm} = P^{\pm}\Psi$ as a variational wave function, and solve the mean field equations based on the variation after parity projection. We obtain the equations for the single particle state of nucleon and meson fields from the variation of the total energy functional of the expectation value, $\delta\frac{\langle\Psi^{\pm}|H|\Psi^{\pm}\rangle}{\langle\Psi^{\pm}|\Psi^{\pm}\rangle} = 0$. This variational condition gives a parity projected relativistic Hartree equations and we solve those self-consistently. The cubic and quadratic sigma meson self-interaction terms make this new scheme very complicate if we try to treat seriously those terms from the point of view of taking the effect of nuclear many-body correlation. We introduce a new concept of the mean field, $\sigma^{p} = \langle\Psi|\sigma|\hat{p}\Psi\rangle$, where $\hat{p}$ is the parity operator. Figure 1 shows that the large energy gain is obtained in the variation after parity projection method, especially in the week coupling region around $(g_{\pi}/g_{\pi}(0))^2 \sim 1$. This energy gain almostly originated in the pionic 2p-2h correlation. The character of the parity projected wave function is that the positive parity state consists of even number of 1p-1h pairs with 0^{-} state. It means that the positive parity projection provides 2p-2h states as a major correction terms. The results obtained in case of the variation before projection also presented for comparison. It is indispensable to solve the finite mean field based on the variation after projection in order to take into account properly the pionic correlation, especially in case of that the coupling is fragile. In this variation after projection scheme, LS-closed shell nuclei also obtain the large pion potential energy per particle.

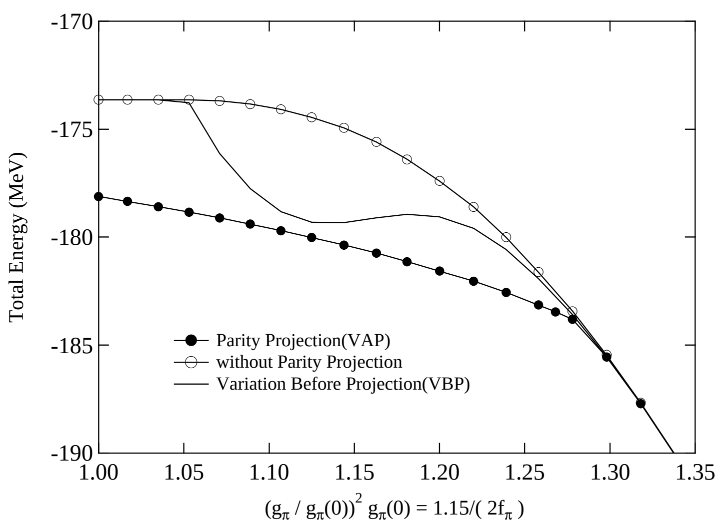

Figure 1: The total energy of ^{16}O as a function of the pion-nucleon coupling constant for the cases with parity projection(VBP), without projection and parity projection after variation(VAP). $g_{\pi}(0)$ is a critical coupling constant where the finite pion mean field arises.

References

[1] Y. Ogawa, H. Toki, S. Tamenaga, H. Shen, A. Hosaka, S. Sugimoto, K. Ikeda, Prog. Theor. Phys. **111**(2004)75.