1 - 11 Properties of Single-particle States in a Fully Self-consistent Particle Vibration Coupling Approach

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The self-consistent mean filed (SCMF) approaches have achieved a great successful in describing various ground state and excited properties of finite nuclei. The mean filed theory is based on the idea of independent particle assumption where the particle moves independently in the average potential producing by the surrounding nucleons and have no interaction with other nucleons. The calculated single-particle level density and the spectroscopic factors are not comparable to the experimental data. In practice, nucleons can make collisions with other nucleons or couple to the collective vibrations of the nucleus, this is related to the concept of dynamical content. To considering the fluctuations of the average mean field potential, one shall go beyond mend field calculation, which means that the average mean field potential is no more static, but energy dependence. The fluctuations of the average mean field potential is usually described by the effective tool, called as particle vibration coupling (PVC). It has been shown that the PVC strongly shifts the energies of single-particle states around the Fermi surface and increases the single-particle level density. In the earlier time, the PVC calculations are not self-consistent since the Woods-Saxon potential is usually adopted at the mean filed calculations, but the interactions as PVC vertex is different from the one in the mean filed. Now the microscopic self-consistent PVC calculations have been performed within the Skyrme energy density functional[1].

Table 1 The neutron single-particle energies in ^{40}Ca given by T44 parameter set

	T44	Pvc central		Pvc central+S. O.		Pvc full		
	$E^{(0)}$	$\triangle E_i$	E_i	$\triangle E_i$	E_i	$\triangle E_i$	E_i	E_{exp}
$1f_{5/2}$	−0.21	−2.00	−2.21	−2.59	−2.80	−2.67	−2.88	−3.38
$2p_{1/2}$	−2.79	−2.68	−5.47	−3.43	−6.22	−4.15	−6.94	−4.76
$2p_{3/2}$	−5.59	−2.78	−8.38	−3.97	−9.56	−4.25	−9.84	−6.76
$1f_{7/2}$	−10.59	−1.10	−11.69	−1.66	−12.25	−1.89	−12.47	−8.62
$1d_{3/2}$	−13.99	−1.16	−15.15	−2.92	−16.91	−3.32	−17.31	−15.64
$2s_{1/2}$	−17.18	−1.51	−18.69	−3.85	−21.03	−4.14	−21.32	−18.19
$1d_{5/2}$	−22.59	−0.49	−23.08	−0.78	−23.37	−0.74	−23.34	−22.39

Recently, the tensor interaction has been paid more attention in explaining the evolution of the single-particle level in exotic nuclei and the multipole giant resonances for finite nuclei[2]. In the past, the central force of Skyrme interaction has been included in the PVC vertex, the non-central part of the Skyrme is dropped in the calculations, such as the spin-orbit and tensor interaction. In this work, we shall study the effect of the non-central part of the Skyrme interaction as the PVC vertex on the single particle properties of finite nuclei, we will discuss the change of the energy of the single particle states, the effective mass when the tensor and the spin-orbit interaction are included in the PVC vertex. We will perform the calculations on nuclei of ^{40}Ca as a test, the Skyrme interactions we adopted here is T44[3]. The ground states and the various excited states of nuclei ^{40}Ca are calculated on the basis of the fully self-consistent HF+RPA framework[4]. The coupling of the particle to the vibrations if derived from the same effective Skyrme force, the including/excluding the tensor or spin-orbit interaction is to see their effect on the single-particle properties.

Table 2 The neutron effective mass in ^{40}Ca obtained by using T44 parameter set

	T44	Pvc central		Pvc central+S. O.		Pvc full	
	m_k^*	m_e^*	m^*	m_e^*	m^*	m_e^*	m^*
$1f_{5/2}$	0.896	1.191	1.067	1.443	1.293	1.438	1.288
$2p_{1/2}$	0.901	1.176	1.060	1.263	1.139	1.293	1.165
$2p_{3/2}$	0.878	1.213	1.065	1.444	1.268	1.478	1.298
$1f_{7/2}$	0.856	1.111	0.951	1.209	1.036	1.227	1.051
$1d_{3/2}$	0.823	1.103	0.907	1.315	1.082	1.357	1.116
$2s_{1/2}$	0.829	1.162	0.964	1.319	1.094	1.341	1.112
$1d_{5/2}$	0.814	1.112	0.905	1.202	0.978	1.294	1.053

Table 1 is the results for neutron single-particle energies in ^{40}Ca calculated in various approximation, the calculated results are compared with the available experimental data. We can see that the single-particle energies becomes more negative when the calculation goes beyond the mean field approximation where only the central part of the interaction is included, especially for $1f_{5/2}$, $2p_{1/2}$, $2p_{3/2}$ neutron states, the energy shift is more than 2 MeV compared to the results give by pure Hartree-Fock calculation. Usually the spin-orbit interaction play an attractive role as the residual interaction in the various giant resonances of nuclei, from table 1 we see that the similar results are obtained by the spin-orbit interaction, it gives an attractive contribution to the single-particle energies when the spin-orbit interaction is included in the PVC vertex, the maximum energy shift is about 2.34 MeV. Finally let us discuss the contribution from tensor interaction, for most of the states, the tensor gives an attractive contributions to the single-particle energies, for $1d_{5/2}$, it gives a slightly repulsive contribution to the energy.

Table 2 shows the effective mass in ^{40}Ca within various approximation. The effective mass is about 0.8~0.9 around the Fermi surface within the pure Hartree-Fock calculation, means it just gives the so-called k-mass. When one goes beyond the mean field calculation, one shall consider the energy-dependent mass operator, we see that the calculated e-mass is in the region 1.1 to 1.5 around the Fermi surface, the total effective mass is the product of k-mass and e-mass, finally effective mass around the Fermi surface is about the unit. We conclude that the level density around the Fermi surface is enhanced when we go beyond the mean field calculation.

References

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1 - 12 Researchers Explored Roles of Nucleon Resonances in Λ(1520) Photoproduction

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The study of nucleon resonance is an interesting area in hadron physics. As of now, the nucleon resonances around 2.1 GeV are still in confusion. The CQM predicted about two dozens of the nucleon resonances in this region, most of which are in $n=3$ shell. Only a few of them have been observed as shown in PDG with large uncertainties[1]. Hence, more efforts should be paid to figure out the nucleon resonances around 2.1 GeV. Due to the high threshold of Λ(1520) production, about 2 GeV, it is appropriate to enrich our knowledge of nucleon resonances, especially ones with mass larger than 2 GeV. In recent years, excited by the claimed finding of the pentaquark Θ with a mass of about 1.540 GeV, many experiments, such as LEPS/Spring-8[2], CLAS/JLab, have been performed in the Λ(1520) energy region due to the close mass of Λ(1520) and Θ. Though the existence of the pentaquark is doubtful based on later more precise experiments, many experimental data on Λ(1520) photoproduction have been accumulated.

In this work we investigate the Λ(1520) photoproduction within the effective Lagrangian method. The contact term is dominant in the interaction mechanism and K exchanged t-channel are important except at the energy near the threshold. The K^*-exchange t-channel plays an important role in the high energy at 11 GeV, but is negligible at low energy. The contributions of nucleon resonances are determined by the radiative and strong decay amplitudes predicted by the constituent quark model. The results shows that D_{13}(2080) is the most important nucleon resonance in Λ(1520) photoproduction and responsible to the bump structure in the LEPS10 experiment as shown in Fig. 1(left). A nucleon resonance $[N5/2^-]_2$(2080) predicted by CQM with mass about 2100 MeV, which cannot be assigned as N(2200), is also essential to reproduce the experimental data around 2.1 GeV. The contributions from other nucleon resonances are small even negligible.