Nucleon Resonances of the Constituent Quarks and the Pions in a Coherent State

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It is widely accepted that the spontaneous breaking of chiral symmetry (SBχS) is the key issue in the low enegy region of QCD. Based on the SBχS, the pion has been introduced to phenomenological models of the hadrons as one of the effective degrees of freedom in addition to the quarks. In the nonrelativistic constituent quark model (NRCQM), the pion has been treated in perturbation theory in spite of the strong quark-pion coupling [1].

In this study we introduce the coherent state of pions to the NRCQM. We employ the coherent pair approximation (CPA) for the pion state, which is one of the nonperturbative representation of the pion field [2]. The CPA state is the eigenstate of spin and isospin, in contrast to the projection method based on the hedgehog ansatz. When the excitation of quarks is taken into account, the CPA may be suitable for the description of the nucleon structure [3]. We construct the nucleon states by combining the CPA states with the three-quark states, and calculate the nucleon mass spectrum. Our results are compared to those of the NRCQM with one pion exchange potential (OPEP) [1].

We have found that in our model the origin of the vertex form factor for the pion-quark interaction is due to the coherent property of the localized pion. As for the N^* structures, the first excited state of positive parity is dominated by the components of the three quarks in the ground state plus one pion, not by the nodal excitation of quarks. Although the nonperturbative treatment of the pion in the CPA does not exlain the nucleon spectrum, our results show that the other degrees of freedom than quarks are important in the study of the nucleon structure.

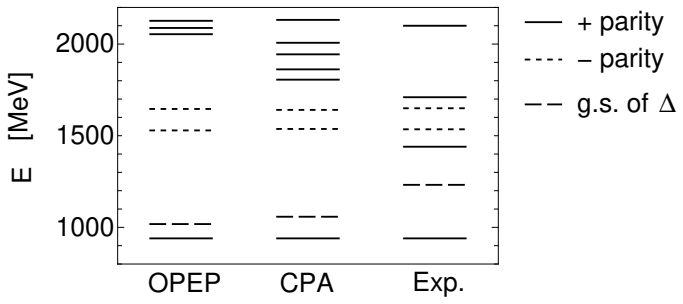

Figure 1: Nucleon spectrum. The parameter set in each model is determined so that the masses of the negative parity states are reproduced.

References

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