Dependence of the H-particle mass on the Effective Meson-Exchange Potentials in a Quark Model

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Since Jaffe predicted the existence of the H-particle, many experimental attempts have been done for searching it. Nevertheless, the H-particle has not been found yet. Does the H-particle really exist? If not, what has gone with the strong attraction generated from the color-magnetic (CM) interaction in this state ?

The H-particle with the strangeness $S = -2$ should be understood on the common foundation to the $S = 0$ and -1 systems. We have recently proposed three models to describe the NN, ΛN and ΣN interactions simultaneously in the RGM framework of the spin-flavor SU_6 quark model. These are called RGM-F [1], FSS [2, 3] and RGM-H [3], respectively. These three models are different from each other only in the treatment of the effective meson-exchange potentials (EMEP). The present quark-model Hamiltonian consists of the non-relativistic kinetic energy term, the quadratic confinement potential, the full Fermi-Breit interaction with explicit quark-mass dependence, and the scalar- (S-) and pseudoscalar- (PS-) meson exchange potentials acting between quarks. The S-meson nonet (ϵ, S, δ, κ) exchange potential includes only the central component. In RGM-F [1], we assumed that the EMEP spin-flavor factors of the RGM kernel are proportional to that of the normalization kernel and the direct terms are proportional to the corresponding pieces of the Nijmegen model-F potential. For the S-meson exchange potentials, we introduced reduction factors which depend on the flavor exchange symmetry between two interacting baryons. These reduction factors are determined to reproduce the NN $^1S_0$ phase shift and the deuteron binding energy. The PS-meson exchange potential includes only the tensor component generated from the π- and K-meson exchanges. In FSS and RGM-H [3], the EMEP spin-flavor factors are explicitly calculated at the quark level and the PS-meson exchange potential includes the spin-spin and tensor components generated from the PS-meson nonet (η', η, π, K) exchanges. In the spin-spin term of the PS-mesons, we have the δ-function type contact term with a common reduction factor c_δ, which is chosen to be $c_\delta = 0.381$ (FSS) or 0.339 (RGM-H) for all channels. We employ the same approximation as adoped in RGM-F for the isoscalar S-meson (ϵ and S^*) exchange potential in RGM-H. We can find in [1, 2, 3] that these models give a reasonable description for the NN phase shifts up to the total angular momentum $J = 4$ and for the low-energy YN scattering cross section data.

Figure 1 shows the $^1S_0$ phase shifts obtained by the channel-coupling calculation in the $I = 0$ system for three models. The $\Lambda\Lambda$-ΞN two-channel calculation, denoted by the dashed curves, gives a bound state with the binding energy of 10 MeV below the $\Lambda\Lambda$ threshold in RGM-F, while it does not give a bound state in FSS and RGM-H. FSS shows a sharp resonance just below the ΞN threshold, and RGM-H has a cusp structure at the ΞN threshold. The introduction of the coupling to the $\Sigma\Sigma$ channel, denoted by the solid curves, does not essentially change this situation. The binding energy in RGM-F further increases up to 19 MeV [4], and the cusp structure appears at the $\Sigma\Sigma$ threshold in all models.

One of the reasons giving the above difference between three models lies in the strength of the attraction of the diagonal $\Xi N(I = 0)$ interaction. Another reason is the difference

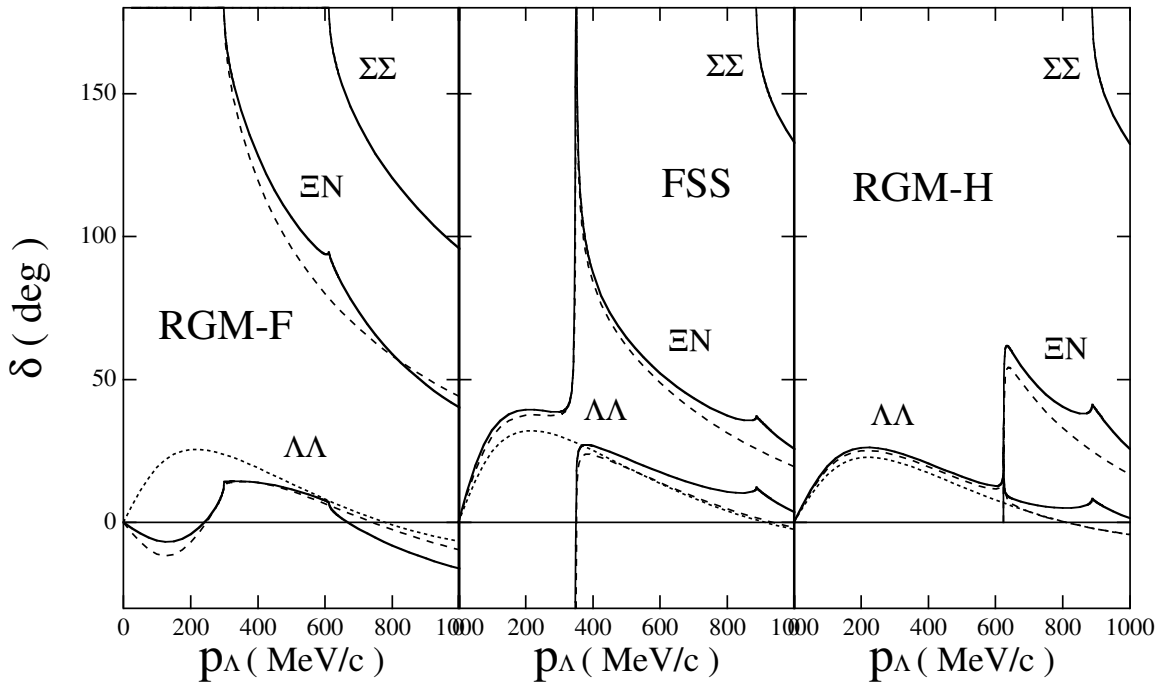

Figure 1: The $^1S_0$ phase shifts of the isospin $I = 0$ state with $S = -2$ in RGM-F, FSS and RGM-H. The dotted curves denote the $\Lambda\Lambda$ single-channel calculation, the dashed curves the $\Lambda\Lambda$-ΞN 2-channel calculation, and the solid curves the $\Lambda\Lambda$-ΞN-$\Sigma\Sigma$ 3-channel calculation.

between RGM-F and other models in the strength of the $\Lambda\Lambda$-ΞN channel-coupling effect. The $\Lambda\Lambda$-ΞN $^1S_0$ transition potential consists of the EMEP contribution and that of the CM term generated from the Fermi-Breit interaction. The EMEP contribution in this channel comes dominantly (in FSS and RGM-H) or exactly (in RGM-F) from the strange-meson exchange. We should note that the EMEP contribution has an opposite sign to that from the CM term. It means that CM contribution is largely reduced by the EMEP contribution. This reduction is comparatively small in RGM-F, while the total coupling potential is extremely small in FSS and RGM-H since they almost cancel out. Moreover, the flavor-symmetry breaking (FSB) generated from the mass difference between quarks gives some difference between RGM-F and other models, with repect to the strength of the CM contribution. The CM term becomes smaller as the effect of the FSB becomes larger and the $\Lambda\Lambda$-ΞN transition potential becomes smaller as the FSB becomes larger. This can be seen from the fact that the binding energy of the H-particle in RGM-F increase from 19 MeV to 64 MeV when $\lambda \equiv m_s/m_{ud} = 1.25$ is modified to $\lambda = 1$ [4]. The actual value of λ is 1.25 for RGM-F, while it is 1.526 and 1.490 for FSS and RGM-H, respectively. This implies that the $\Lambda\Lambda$-ΞN transition potential generated from the CM term of RGM-F is larger than those of FSS and RGM-H.

References

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