$\Lambda(1405)$ in a baryon-meson scattering described from a quark-model viewpoint

Sachiko Takeuchi
Japan College of Social Work, Kiyose, Tokyo 204-8555, Japan
Contact e-mail: s.takeuchi@jcsw.ac.jp

Kiyotaka Shimizu
Department of Physics, Sophia University, Chiyoda-ku, Tokyo 102-8554, Japan

The properties of $\Lambda(1405)$ is hard to understand from the conventional quark-model framework. It assumes the flavor-singlet q^3 $(0s)^2(0p)$ configuration, but cannot give the observed light mass, nor the large splitting between $\Lambda(1405)$ and $\Lambda(1520)$. Also, in such a quark model the contribution from the baryon-meson continuum is not taken into account, which is necessary because it has a large width. Recently, it was reported that a baryon-meson model with the chiral unitary approach can reproduce the peak without the help of an quark pole [1]. It, however, raises a new question: there should be the flavor-singlet q^3 state, which is supposed to affect the baryon-meson scattering in this energy region.

In this work, we have investigated q^3-$q\bar{q}$ scattering system with the flavor-singlet q^3 $(0s)^2(0p)$ pole in order to describe $\Lambda(1405)$ as a resonance in the baryon-meson scattering. For that purpose, we employ the Quark Cluster Model (QCM), where the pole is treated as a bound state embedded in the continuum. The effective quark interaction consists of the one-gluon exchange and the instanton-induced interaction as well as the linear confinement potential. There is no strong attraction in the $N\overline{K}$ channel in such a model. With a parameter set which reproduces both of the observed S-wave octet baryon and meson mass spectra, we perform the $\Sigma\pi$-$N\overline{K}$ coupled channel QCM.

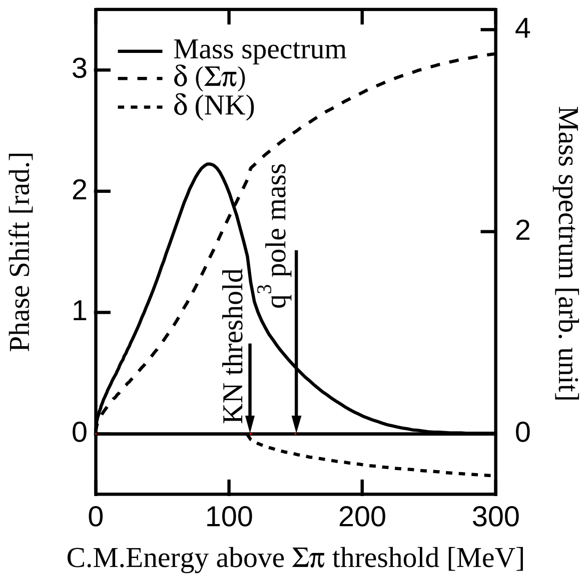

Figure 1: Mass spectrum and the phase shift (δ) of the $\Sigma\pi$ and $N\overline{K}$ coupled channel QCM.

It is found that the peak can be below the $N\overline{K}$ threshold even if the mass of the q^3 pole without the coupling is taken to be the conventional quark model value, which is above the threshold. The peak disappears when the coupling to the q^3 pole is switched off. The obtained peak width agrees with the experiments reasonably well. The $N\overline{K}$ scattering length is roughly half of the observed value [2].

To investigate the mechanism and condition to form the peak, we employ a simple baryon-meson model with a separable interaction with the semi-relativistic kinematics. It is found that the model with the flavor-flavor type interaction can reproduce the peak without introducing an extra pole if the cutoff energy of the baryon-meson interaction is high. This situation is like the chiral unitary approach. When one uses the form factor which corresponds to the baryon and meson sizes in the quark model, however, the effective cutoff becomes lower, and the interaction becomes weaker. In such a case, the model requires an extra pole, which can be considered as the flavor-singlet q^3 pole, to reproduce the observed peak and the $N\overline{K}$ scattering length. When we employ the baryon-meson interaction whose channel dependence is like the color-magnetic interaction, it is also found that the model reproduces a peak similar to the original one by introducing the q^3 pole.

We argue that both of the pole originated from the quark degrees of freedom and the baryon-meson continuum play important roles to form the $\Lambda(1405)$ resonance.

1. E. Oset and A. Ramos, Nucl.Phys.A**635**, 99(1998); T. Hyodo, *et al*, Phys.Rev.C**78**, 025203 (2008)
2. S. Takeuchi and K. Shimizu, Phys.Rev.C**76**, 035204 (2007)