Low-lying baryons in hybrid quark model

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The Roper resonance $N^*(1440)$, the lowest nucleon excited state, has been subjected to intense discussions since its discovery in 1964. In the three-quark picture the first radial excitation state of the nucleon is commonly assigned to the Roper resonance since its quantum numbers are the same as the nucleon's. But detailed studies reveal that it is very difficult to interpret the resonance as a three quark state due to its low mass and strange coupling constants with nucleon and meson. Because of the failure of the three-quark picture, various other model have also been suggested, but none is very successful.

In this work we study the structure of the Roper resonance, via its decay processes. We go along with the argument that the Roper resonance is a state of three quarks and one transverse-electric (TE) gluon, q^3G, namely, a hybrid baryon. A nonrelativistic quark-gluon model is employed, where the dynamics of antiquark-quark-gluon is described in the effective $^3S_1$ vertex in which a quark-antiquark pair is created (destroyed) from (into) a gluon. The wave function of the Roper resonance is properly constructed to take into account the gluon freedom in the nonrelativistic regime. As the approach developed in the work is very general, we have extended the model to study the decay processes of the $\Delta(1600)$. The evaluated decay width ratios $\Gamma_{N^*(1440)\to N\rho}/\Gamma_{N^*(1440)\to N\pi}$, $\Gamma_{N^*(1440)\to N\eta}/\Gamma_{N^*(1440)\to N\pi}$, $\Gamma_{N^*(1440)\to N\sigma}/\Gamma_{N^*(1440)\to N\pi}$, $\Gamma_{N^*(1440)\to\Delta\pi}/\Gamma_{N^*(1440)\to N\pi}$, $\Gamma_{\Delta(1600)\to\Delta\pi}/\Gamma_{\Delta(1600)\to N\pi}$, $\Gamma_{\Delta(1600)\to N\rho}/\Gamma_{\Delta(1600)\to N\pi}$ and $\Gamma_{\Delta(1600)\to N^*(1440)\pi}/\Gamma_{\Delta(1600)\to N\pi}$ are in good agreement with experimental data.

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