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Theoretical interpretations of exotic hadrons

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In the naive quark model, baryons and mesons are bound states of three quarks and quark-antiquark pair, respectively. However, Exotic hadrons such as tetraquark ($q^2\bar{q}^2$), pentaquark ($q^4\bar{q}$), hexaquark ($q^3\bar{q}^3$), and even quark-gluon hydrid (q^3G) and glueball are not forbidden in the framework of QCD. Some exotic hadron states may possess quantum numbers which are not accessible by the traditional $q\bar{q}$ and q^3 hadron states. In this talk we will summarize all potential exotic hadrons, particularly the recently observed Charmonium-like X, Y, and Z tetraquark particles and P_c pentaquark states.

The nature of any exotic hadron still remains an open question with diverged interpretations. Among various theoretical pictures, constituent quark models, chiral perturbation theory, effective field theories, dynamical models like triangle singularity, Lattice QCD, and QCD sum rules have been proposed to explain the quantum numbers, decay patterns, mass spectrum and internal structures of the exotic hadrons. For the Charmonium-like X, Y, and Z tetraquark particles and P_c pentaquark states, the compact multi-quark picture and hadronic molecular picture are the widely accepted interpretations. We will brief all the popular theoretical models.

%Group theory approach is a very tool for constructing the multiquark system,
A special attention will be paid on tetraquark and pentaquark states, showing how the wave functions of light and heavy tetraquark and pentaquark states may be systematically constructed in the language of group theory. As an example, we will briefly introduce a constituent quark model applied to derive the mass spectrum and strong decay widths of pentaquarks, considering the coupling between the $\Sigma_c^{(*)}\bar{D}^{(*)}$ molecular states and the $q^3c\bar{c}$ compact pentaquark states.

Finally we propose that the isospin-1/2 narrow resonance $N^+(1685)$ could be the lowest compact pentaquark state, based on our recent work.

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