Studies of exotic hadrons by high-energy exclusive reactions

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Hadrons are classified into two categories, mesons and baryons. According to a naive quark model, the mesons and baryons have the configurations of $q\bar{q}$ and $qqq$, respectively. Since the underlying fundamental theory of strong interactions (QCD) does not prohibit different forms of configurations such as tetraquark ($qq\bar{q}\bar{q}$) and pentaquark ($qqqq\bar{q}$), exotic hadrons have been searched experimentally for a long time since 1960’s. It is fortunate that some exotic hadron candidates have been reported in the last several years particularly by the Belle and BaBar collaborations. Nevertheless, it is rather difficult to find an undoubted evidence because similar theoretical results could be obtained for global quantities such as spins, parities, masses, and decay widths even by conventional $q\bar{q}$ and $qqq$ models although there are some indications, for example, that $f_0(980)$ and $a_0(980)$ could be tetraquark or $K\bar{K}$ molecule and that $\Lambda(1405)$ could be a pentaquark or $\bar{K}N$ molecule.

Here, we propose new approaches to the exotic-hadron studies by using high-energy hadron reaction processes \[1,2\], where quark and gluon degrees of freedom appear. First, we consider the two-photon process $\gamma^*\gamma \rightarrow hh$ for probing internal structure of the hadron $h$ such as $f_0(980)$ and $a_0(980)$ \[1\]. Exotic signatures appear in generalized distribution amplitudes (GDAs) which can be measured in the two-photon process. The GDAs correspond to the GPDs (generalized parton distributions) by the $s$-$t$ channel crossing. The studies of the GDAs together with the GPDs should shed light on a new aspect of exotic-hadron physics for future developments in clarifying the existence of exotics and their internal quark-gluon configurations \[1\].

Next, we propose to use hard exclusive production of an exotic hadron, by taking $\Lambda(1405)$ as an example, for finding its internal quark configuration \[2\]. In particular, the cross section for the exclusive process $\pi^- + p \rightarrow K^0 + \Lambda(1405)$ is estimated at the scattering angle $\theta_{cm} = 90^\circ$ in the center-of-mass frame by using exiting experimental data and a theoretical model. We suggest that the internal quark configuration of $\Lambda(1405)$ should be determined by the asymptotic scaling behavior of the cross section in comparison with the ordinal-\Lambda production. Such measurements will be possible, for example, by using the high-momentum beamline at J-PARC \[2\].

\[1\] H. Kawamura and S. Kumano, KEK-TH-1589, to be submitted for publication.
\[2\] H. Kawamura, S. Kumano, and T. Sekihara, KEK-TH-1623, to be submitted for publication.