Internal structure of $f_0(980)$ by fragmentation functions

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In this study, we discuss the quark structure of an exotic hadron by using fragmentation functions (FFs). In the high energy e^+e^- scattering process, several kinds of hadrons are produced, and the FFs of the hadron are obtained by a global analysis with the experimental data. The FF has information of hadronization, and is interpreted as a probability density for hadron production from the parent quark in the e^+e^- annihilation process ($e^+e^- \to q\bar{q} \to h + X$). The function contains the non-perturbative part, which must be obtained from the experimental data. It is a function of scaling valuable z which is defined by the ratio of the energies of the produced hadron and parent quark; $z = E_h/E_q$. Then, there are two types; namely the favored and disfavored types. The favored type has a peak in the medium-, and large-z region. It means that the quark becomes a seed of the produced hadron, and it corresponds to the valence quark in the hadron. The function of disfavored type has a peak in the small-z region, and it seems to be sea quark in the analogy with the parton distributions. Studying the behavior of the FFs, we can know which flavor is the main component of the produced hadron. Thus, a clue of internal quark structure can be obtained from the FFs of the exotic hadron. We have determined the FFs of the $f_0(980)$ meson as a exotic hadron, and discuss its quark structure.

To discuss the structure, we consider four configurations; non-strangeness $q\bar{q}$, $s\bar{s}$, tetra-quark, and glueball. The configuration can be chosen by using the relations of second moments and that of the peak positions for the obtained FFs. For instance, by using the relation of the peak position, if the peak of the FF for the s ($\bar{s}$) quark is in the large-z region and that of light quarks (u, $\bar{u}$, d, $\bar{d}$) are the small-z region, the FF for the s quark is in the favored type and that for light quarks are in the disfavored type. It means that s quark is the valence quark and light quarks are the sea quarks in the meson, such that indicates the possibility of the $s\bar{s}$ configuration. If the peak of the FF for the light and s quarks show the same behavior of the favored type, it means these quarks are the valence quark, thus the tetra-quark configuration is chosen. In addition, by using the relation of the second moments, the quark configuration can be determined.

The FFs are determined by a global analysis using the hadron production data in the e^+e^- scattering experiments [1]. Details of the analysis is given in the paper [2, 3]. The obtained FFs are shown in Fig. 1. In the figure, the peak position of the function for the light or s quark exists at $z = 0.85$, and thus it shows the behavior of the favored type. This fact indicates the possibility that these flavors are valence quarks in the $f_0(980)$ meson, and it chooses the tetra-quark configuration as the quark structure. However, the value of the second moment is 0.0012 ± 0.0107 for the light quark, and 0.0027 ± 0.0183 for the s quark. The value of the light quark is less than that of the s quark. It indicates that the $s\bar{s}$ configuration is favored.

This contradiction is caused by the low accuracy of the experimental data. Uncertainties of the

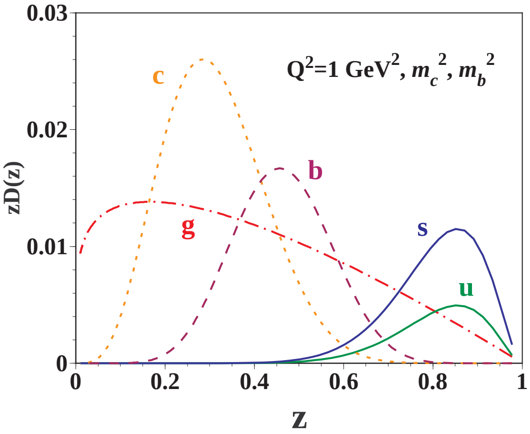

Figure 1: Obtained fragmentation functions of $f_0(980)$ by the global analysis. The functions $zD_u^{f_0}$, $zD_s^{f_0}$, and $zD_g^{f_0}$ are shown at Q^2=1 GeV^2, and the functions for the heavy quarks are at $Q^2 = m_c^2$ and m_b^2, respectively.

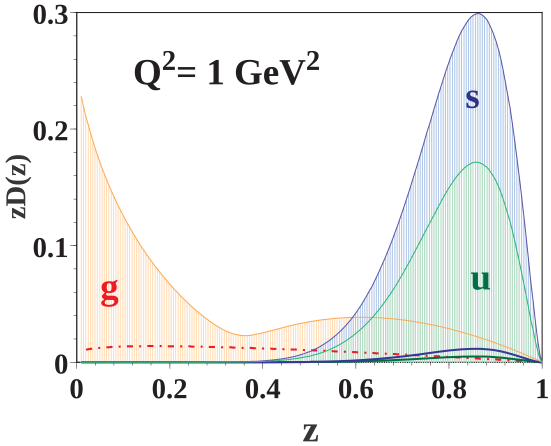

Figure 2: Uncertainties of the obtained fragmentation functions for light, s quark, and gluon at Q^2=1 GeV^2.

obtained FFs are shown in Fig. 2. These functions have the huge uncertainties, and these second moments also have large errors. Therefore, we cannot determine the quark configuration of the $f_0(980)$ meson at present. To choose uniquely, the uncertainties have to be reduced by including precise measurements. In addition, the determination of the FF for the gluon needs the data covering wide range of $Q^2(=\sqrt{s})$, because the gluon function contributes to the cross section via the Q^2 evolution. Since rather large $Q^2(=M_z^2)$ data exist, lower Q^2 data play important role in the determination. The data from the Bell and BarBar experiments therefore are expected to improve the current situation.

References

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