Formation of $\eta'(958)$-mesic nuclei and axial $U_A(1)$ anomaly at finite density

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In the contemporary hadron physics, the light pseudoscalar mesons (π, K, η) are recognized as the Nambu-Goldstone bosons associated with the spontaneous breaking of the QCD chiral symmetry. In real world, these mesons, together with heavier $\eta'(958)$ meson, show the involved mass spectrum, which are believed to be explained by the explicit flavor $SU(3)$ breaking due to current quark masses and the breaking of the axial $U_A(1)$ symmetry at the quantum level referred as the $U_A(1)$ anomaly [1, 2].

However, as for the behavior of the $U_A(1)$ anomaly in the nuclear medium, the present exploratory level is rather poor. Although some theoretical results have been reported not only in vacuum but also at $T \neq 0$ and/or $\rho \neq 0$, there exists no experimental information on the possible effective restoration of the $U_A(1)$ anomaly at finite density. In this study, we propose the formation reaction of the η- and η'-mesic nuclei in order to investigate the η' properties, especially mass shift, at finite density [3, 4]. Since the huge η' mass is believed to have very close connection to the $U_A(1)$ anomaly, the η' mass in the medium should provide us important information on the effective restoration of the $U_A(1)$ symmetry in the nuclear medium.

We discuss the possibility of producing the bound states of the $\eta'(958)$ meson in nuclei theoretically using the the Nambu-Jona-Lasinio (NJL) model. We calculate the formation cross section of the η' bound states with the Green function method for the (γ,p) reaction (Fig.1) and discuss the experimental feasibility at photon facilities such as SPring-8 in Refs. [3, 4]. We conclude that we can expect to observe resonance peaks in (γ,p) spectra for the formation of η' bound states and we can deduce new information on η' properties at finite density. Detailed discussions are given in Refs. [3, 4]. These observations are believed to be essential to know the possible mass shift of η' and deduce new information on the effective restoration of the chiral $U_A(1)$ anomaly at finite density.

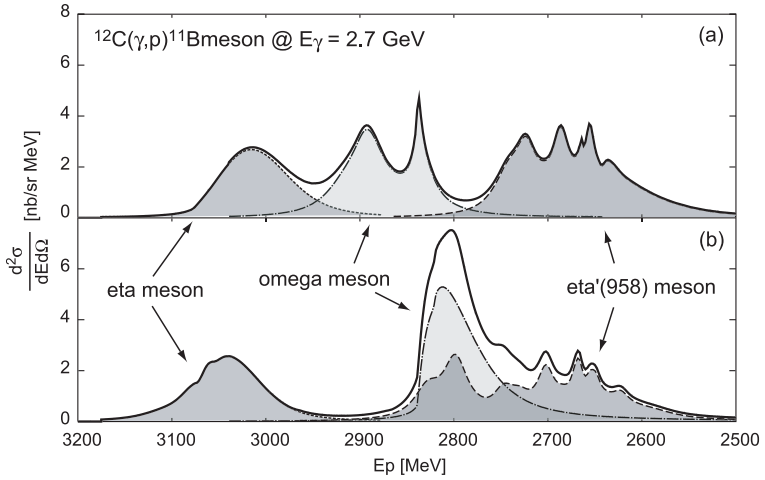

Figure 1: Formation spectra of the η- and η'-mesic nuclei together with the ω-mesic nuclei as functions of the emitted proton energy in the ^{12}C(γ,p) reaction with (a) constant g_D case and (b) energy dependent g_D case.

The experiment for the formation of the ω-mesic nucleus is already planed at SPring-8. So we expect that the η and η' mesons also can be observed by this experiment and expect to obtain new information on the η' meson and the $U_A(1)$ anomaly effect in finite density. We believe that the present theoretical results are important to stimulate both theoretical and experimental activities to study the $U_A(1)$ anomaly effect at finite density and to obtain the deeper insights of the QCD symmetry breaking pattern and the meson mass spectrum.

References

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