Formation of the $\eta'(958)$ mesic nuclei by missing mass spectroscopies

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The mass of the $\eta'(958)$ pseudoscalar meson is much heavier than other octet pseudoscalar mesons, which is known as the $U_A(1)$ problem. Because the $U_A(1)$ symmetry is explicitly broken by quantum anomaly, the η' meson is not necessarily a Nambu-Goldstone boson associated with spontaneous chiral symmetry breaking. However, we have not yet understood quantitatively generation mechanism of the mass of the η' meson.

Since the chiral symmetry breaking plays important role in the generation mechanism of the η' mass [1, 2], the study of the in-medium mass of the η' meson gives us important information on the generation mechanism and the partial restoration of chiral symmetry. In Ref. [2], it has been pointed out that the anomaly effect can contribute to the mass of the η' meson only with the presence of the chiral symmetry breaking, and a relatively large mass reduction (~ 100 MeV) of the η' meson at normal saturation density is expected owing to the partial restoration of chiral symmetry at finite density. Since the mass reduction at finite density is considered to be equivalent to the existence of the attractive potential in the equation of motion, we can expect to observe the η'-nuclear bound states in appropriate formation reactions. The formation reactions of the η' mesic nuclei was first considered in [3] by using the (γ,p) reaction and are considered to be possible at existing facilities like SPring-8 and/or GSI [3, 4, 5].

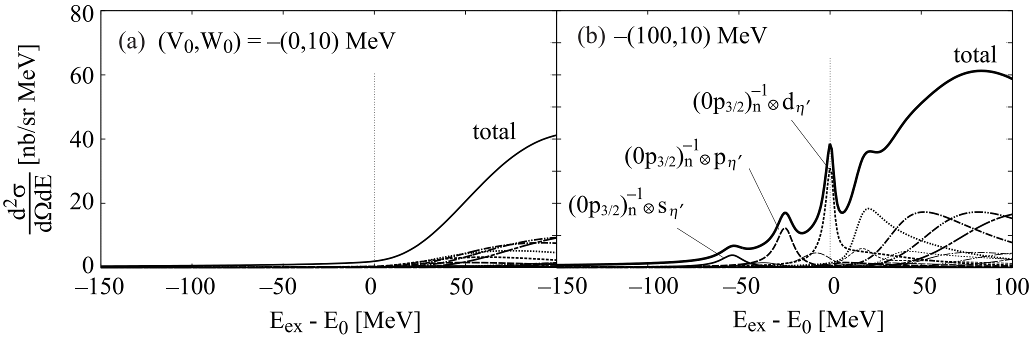

Figure 1: Calculated spectra of ^{12}C$(p,d)^{11}$C$\otimes\eta'$ reaction for the formation of the η'-nucleus systems with the proton kinetic energy $T_p = 2.5$ GeV and the deuteron angle $\theta_d = 0°$ as functions of the excited energy $E_{\rm ex}$. E_0 is the η' production threshold. The depth of the η'-nucleus optical potential is (a) $(V_0, W_0) = -(0, 10)$ MeV, and (b) $(V_0, W_0) = -(100, 10)$ MeV. The thick solid line shows the total spectrum and dashed lines indicate subcomponents. The neutron-hole states are indicated as $(n\ell_j)_n^{-1}$ and the η' states as $\ell_{\eta'}$.

In Fig. 1 we show the formation spectra of η'-mesic nuclei by the (p, d) reaction with the proton kinetic energy $T_p = 2.5$ GeV. The detailed discussions for the (p,d) spectra are given in Refs. [4, 5]. The potential depth is set to be $-(0, 10)$ MeV and $-(100, 10)$ MeV. As we can see from the figure, the use of a strongly attractive potential admitting bound states gives rise to clear peak structures and there is a clear difference between the spectra obtained using attractive or non-attractive potentials. In Refs. [4, 5, 6] we show formation spectra for various cases. The results are important to give predictions and supports to the future experiments, and to make clear relation between the η' mesic nucleus formation spectra and the modifications of the η' properties at finite density.

References

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