Study of $\eta \to 3\pi$ decay in nuclear medium based on chiral effective models

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Abstract:

In this thesis, we investigate the $\eta \to \pi^+\pi^-\pi^0$ and $3\pi^0$ decay widths in the nuclear medium using the two different approaches, a non-linear and linear sigma models.

First, we study the η-π^0 mixing angle and the decay widths of the η meson into three π based on the non-linear sigma model. These quantities originate from the isospin-symmetry breaking and it is expected that they are affected by the isospin asymmetry caused by the asymmetric nuclear medium. We find that the mixing angle is enhanced in the neutron-rich nuclear medium and suppressed slightly by the nuclear density ρ. Our calculation shows the enhancements of the decay widths by the asymmetric nuclear density $\delta\rho$ and the additional large effect from the nuclear density ρ. The widths of the $\eta \to \pi^+\pi^-\pi^0$ and $3\pi^0$ processes in the nuclear medium become at most three and two times larger than those in the free space. For the enhancements by the nuclear density, we find the significant role of the c_1 term in $\mathcal{L}^{(2)}_{\pi N}$, which has a connection with the contribution from the sigma meson within its heavy-mass limit. Hence, we expect that the enhancement occurs in association with the dynamics of the sigma meson in the nuclear medium. The dependences of these decay widths on the nuclear asymmetry $\alpha \equiv \delta\rho/\rho$ show different tendencies; the dependence on the nuclear asymmetry α of the $\eta \to \pi^+\pi^-\pi^0$ decay width comes from the η-π^0 mixing angle and it is suppressed by the Bose symmetry in the $\eta \to 3\pi^0$ decay.

Next, we analyze these decay widths using the linear sigma model aiming to clarify the role of the sigma meson for the in-medium η decays. In this study, we concentrate on the symmetric nuclear medium in order to focus on the effect of the sigma meson. The decay widths are enhanced by a factor of at most about four to ten in comparison with those in the free space depending on the mass of the sigma meson in the free space which is an input parameter of this calculation. Moreover, the enhancements are significant even in the small density; the decay widths are several times larger than those in the free space at a half of the normal nuclear density with a relatively small dependence on the sigma mass at $\rho = 0$. These enhancements are caused

by the softening of the sigma meson associated with the chiral restoration in the nuclear medium. Hence, the decay widths of the η meson into three π can be new possible probes for the chiral restoration. It is found that the $\eta \to 3\pi^0$ decay width is enhanced moderately compared with the $\eta \to \pi^+\pi^-\pi^0$ one in the nuclear medium. This is because the softening of the sigma meson in the nuclear medium causes a cancellation of the terms appearing from the Bose symmetry in the $\eta \to 3\pi^0$ process. The significant difference of the enhancements between the $\eta \to \pi^+\pi^-\pi^0$ and $3\pi^0$ decay widths may help us in the experimental investigation of these modifications of the decay widths.