Chiral condensate in nuclear matter beyond linear density using chiral Ward identity

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In low-energy Quantum ChromoDynamics, spontaneous breaking of chiral symmetry is one of the most important phenomenon because this is responsible for the generation of the constituent quark mass. We focus on partial restoration of chiral symmetry in a finite density environment such as inside of atomic nucleus. Partial restoration of chiral symmetry can be observed by investigating the modification of hadron properties in nuclear matter. To examine partial restoration of chiral symmetry in nucleus experimentally, binding energy and width of 1s state of deeply bound pionic atom is measured precisely [1]. This experiment suggests that the chiral condensate which is an order parameter of the chiral symmetry breaking is reduced by about 30 % at the nuclear density.

In our work [2], we analyze density corrections of the chiral condensate up to NLO order using the chiral Ward identity [3] and an in-medium chiral perturbation theory [4,5]. The in-medium chiral condensate is calculated by a correlation function of the axial current and pseudoscalar density in nuclear matter as a consequence of the chiral Ward identity. The correlation function is evaluated using the chiral perturbation theory with the hadronic quantities of pion and nucleon dynamics. We assume that all of the in-vacuum interaction vertices are known and in-vacuum loop corrections are supposed to be done by using the experimental values of the couplings in the calculation of the chiral condensate. This procedure leads to a density (fermi momentum) expansion of the chiral condensate. Based on this density expansion approach, we analyze diagrammatic structure of the current Green function which gives density effects to the condensate. This analysis shows that medium effects to the chiral condensate beyond linear density come from density corrections to πN sigma term due to interactions between pions and nuclear matter.

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