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$\Sigma_c \bar{D}^{(*)}$ interaction in chiral perturbation theory

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We employ the heavy hadron chiral perturbation theory (HHChPT) to calculate the $\Sigma_c \bar{D}^{(*)}$ potentials to the next-to-leading order. The contact, the one-pion exchange and the two-pion exchange interactions are included. We keep the mass splittings between the heavy quark spin symmetry (HQSS) multiplets in calculation. We show that neglecting the heavy quark symmetry (HQS) violation effect may be misleading to calculate the charmed hadron potential. We give three scenarios to do numerical analysis. In the first scenario, we relate the low energy constants (LECs) for contact terms of $\Sigma_c \bar{D}^{(*)}$ to those of nucleon systems. We reproduce the $P_c(4312)$ and $P_c(4440)$ as loosely bound states. In the second scenario, we vary the unknown LECs and find a small parameter regions in which $P_c(4312)$, $P_c(4440)$ and $P_c(4457)$ can coexist as molecular states. In the third scenario, we include the couple channel effect on the basis of scenario II. We can reproduce the three P_c states simultaneously in a large region of parameters as molecular states. Our numerical results for now is rough without the experimental data as input. We call for the lattice QCD simulation on the $\Sigma_c \bar{D}^{(*)}$ potentials. Our analytical results can be used for the chiral extrapolation. With the lattice QCD results as input, identification of P_c states and prediction in this work can be more precise.

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