Formation of deeply bound pionic atoms in Sn isotopes

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Deeply bound pionic atom is one of the best systems to deduce pion properties at finite density and to obtain precise information on the partial restoration of chiral symmetry in nuclei. In ref. [1], the binding energy and width of the 1s states have been precisely measured in three Sn isotopes and isospin-density dependence of the s-wave pion-nucleus potential has been deduced. From these observations, reduction of the chiral order parameter $\langle\bar{q}q\rangle$ in nucleus was concluded [1, 2].

To develop the studies of pion properties and symmetry restoration in nuclei further, we think that we need to obtain improved and systematic information on deeply bound pionic states. For example, we need more systematic information on the bound states for the unique determination of the pion-nucleus interaction, which is required to fix the potential strength related to chiral symmetry [2].

In this report, we consider theoretically the new possibility to observe various deep pionic bound states in the same nuclei by observing the $(d,^3\mathrm{He})$ spectra at finite angles together with the forward direction [3]. These observations have been performed in the high precision experiments at RIBF/RIKEN [4]. We study the formation of deeply bound pionic atoms in the $(d,^3\mathrm{He})$ reactions at finite angle theoretically and show the angular dependence of the expected spectra. We find that the different combinations of the pion-bound and neutron-hole states dominate the spectra at different scattering angles because of the matching condition of the reaction. We conclude that we can study several deeply pionic bound states in a certain nucleus by observing the spectra at finite angles in addition to the forward direction. The calculated results will be compared with the latest data [4].

We also study the formation of deeply bound pionic atoms in the $(d,^3\mathrm{He})$ reactions on the odd nuclear target, which has not been investigated so far. This study will provide additional information on the pionic atom formation reactions and the pion properties in nuclei. This experiment will be performed at RIBF/RIKEN in near future [5].

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