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Kaonic nuclear state search at J-PARC

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Collaboration

Abstract content

The $\bar{K}N$ interaction is known to be strongly attractive from low-energy scattering data [1] and X-ray spectroscopy of kaonic atoms [2]. It is widely accepted that the $\Lambda(1405)$ is K^-p bound state / penta-quark or at least strongly couple to that state. The natural expectation of this assumption is that the kaonic nuclear bound state will be formed, and accordingly, such states are predicted and the high density matter formation exceeding the normal nuclear density is expected in such states [3,4]. Therefore, observation of a kaonic nuclear bound state would provide definitive information on the $\bar{K}N$ interaction below threshold, as well as the nature of $\Lambda(1405)$. Both theoretical and experimental studies have been made in the last decade. In particular, strong attention has been paid to the simplest kaonic nuclear state $\bar{K}NN$. Theoretically, all calculations predict the existence of a bound state. However, the predicted $\bar{K}NN$ pole positions, depending on $\bar{K}N$ interaction models, are scattered. For the energy-independent model (static calculation), the binding energy is reaching up to 50-100 MeV [4-11], while in energy-dependent case, it becomes weaker to be 10-30 MeV [11-13]. The widths are also widely scattered over 30-110 MeV/c^2. Experimentally, there are many reports on observed peak structure $\sim$100 MeV below $\bar{K}NN$ threshold. The first report from FINUDA group showing a peak structure in the back-to-back Λp invariant mass spectra via the stopped kaon reaction on ^{6}Li, ^{7}Li, and ^{12}C targets [14], having binding energy (B.E.)$\sim$115 MeV, having a width (Γ)$\sim$70 MeV/c^2 . The DISTO group observed $\bar{K}NN$ decaying to Λp in pp collision at B.E. $\sim$ 100 MeV, having $\Gamma\sim$120 MeV/c^2 [15]. Conversely, no significant structure was observed in a SPring-8/LEPS γ induced inclusiveexperiment [16] or in a proton-proton interaction at HADES/GSI [17]. Also, for the kaon stopped reaction, theother interpretations (i.e. two-nucleon absorption of kaons, which have the final state (Λp or $\Sigma^0 p$) are widely discussed [18,19]. Thus, the evidence for kaonic nuclei remains controversial. To clarify the situation, two independent experimental groups, E15 and E27, are conducting experiments at J-PARC searching for $\bar{K}NN$ bound state. J-PARC E15 and E27 utilizing different reaction channels. The E15 is utilizing ^{3}He(K^-, n) reaction by K^- momentum at 1 GeV/c, while the E27 is utilizing $d(\pi^+, K^+)$ reaction by π^+ momentum at 1.7 GeV/c. The E27 was conducted much earlier than the E15, since the pion beam is more easy to obtained, and published their final result already [20]. According to their paper, they reported that they observed "K^-pp" -like structure at B.E. $\sim$100 MeV, having $\Gamma \sim$ 150 MeV/c^2 , in the $\Sigma^0 p$ decay mode. Their result on binding energy and width is not pretty much consistent with other positive results. The detected decay mode is also different. In an attempt to clarify this situation, the E15 experiment on the K^-+^3He reaction is under way at J-PARC. The first physics data E15 1st. were accumulated in May 2013. The semi-inclusive forward neutron spectrum in the E15 1st. data has a long sub-threshold tail reaching $\sim$100 MeV below the $\bar{K}NN$ threshold, but no significant structure was seen in the deeply bound region [21]. They also conducted inclusive analysis on E15 1st. data for Λpn final state. In this analysis, they used ^{3}He$(K^-, \Lambda p)n_{mis.}$ reaction channel by kinematically identifying missing neutron. They found a broad peak structure near / slightly below the $\bar{K}NN$ threshold, [22] which is quite different from all the other positive channel. To clarify this structure near the threshold, they conducted high statistic run as E15 2nd., in which they accumulated roughly 50 times data for the Λpn final state, and the analysis of E15 2nd. data is in progress. The paper covers present experimental results from these two groups at J-PARC to search for deeply bound kaonic nuclear state, and recent progress of their analysis.

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