Conjecture: a possible $nn\Lambda$ resonance

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The HypHI Collaboration reported evidence that the $nn\Lambda$ system is bound (the hypernucleus ${}^3_\Lambda n$) based upon observation of the two-body and three-body decay modes.[1] This claim is significant because ${}^3_\Lambda n$ would be the lightest neutron-rich hypernucleus and would provide a significant constraint upon the heretofore unmeasured $n\Lambda$ interaction. One can conjecture that such a bound state could be observed directly in a ${}^3\mathrm{H}(\mathrm{e},\mathrm{e}'\mathrm{K}^+){}^3_\Lambda\mathrm{n}$ reaction at JLab, even though such a weakly bound state would imply a small cross section.

Three theoretical analyses have suggested that such a ${}^3_\Lambda n$ bound state should not exist.[2-4] On simple physics grounds, one would not expect a ${}^3_\Lambda n$ bound state: The $T = 0$ hypertriton is just bound [$B_\Lambda({}^3_\Lambda\mathrm{H}) = 0.13 \pm 0.05$ MeV], so that we do not expect the $T = 1$ $nn\Lambda$ system to be bound; in switching from the $T = 0$ to the $T = 1$ state one must replace the ${}^3\mathrm{S}_1$-${}^3\mathrm{D}_1$ $n-p$ interaction, which possesses a bound state, by the ${}^1\mathrm{S}_0$ $n-n$ interaction, which supports only an anti-bound state. However, the interesting question that we would like to address is: Could there exist a three-body resonance in the $T = 1$ $nn\Lambda$ system even though all of the interactions are predominantly s-wave? If such is the case, then one might use the electro-production reaction as a means to explore the $n\Lambda$ interaction.

To examine this possibility, we consider the $nn\Lambda$ system with pairwise interactions represented by rank one separable potentials that fit effective range parameters for the $n-n$ system and for the $N\Lambda$ system effective range parameters resulting from various Nijmegen one-boson exchange potentials[5]. The use of rank one separable potentials allows us to very simply analytically continue the Faddeev equations onto the second sheet of the complex energy plane in search of resonance poles by examining the eigenvalue spectrum of the kernel of the Faddeev equations, as we have done previously for $\Lambda - d$ scattering.[6]

We present an investigation of the trajectory for the pole in the $nn\Lambda$ amplitude as one changes the strength s of the $n\Lambda$ potential. We discuss the difference between two-body and three-body singularities; the three-body case results in a log branch point rather than a square root branch point. Whereas the $n\Lambda$ system has an anti-bound state, the $nn\Lambda$ system can form a resonance. We follow the resonance pole as the strength s is increased until we obtain a ${}^3_\Lambda n$ bound state. In contrast to the tri-neutron case[7], which requires a substantial scale factor, the $nn\Lambda$ system requires only a change in strength of the $n\Lambda$ potential within the experimental uncertainty for the $p\Lambda$ interaction in order to generate a resonance.

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