Possible ΣNN Resonant States

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Brief Outline

- The JLab ^{3}H(e,e$'$ K$^+$)Λnn tritium experiment (previous talk by B. Pandy)
- Structure seen above the Λnn resonance
- No $\mathrm{T} = 2$, ΣNN resonance
- Possible resonances: $\mathrm{T} = 0, 1$
- Theoretical model results
- Summary

The JLab ^{3}H(e,e′ K$^+$)Λnn tritium experiment

- The HypHI collaboration reported seeing a $^3_\Lambda$n bound state. [C. Rappold *et al.*, Phys. Rev. C **88**, 041001(R) (2013).] Given our knowledge of the nn interaction, such a $^3_\Lambda$n bound state would provide a strong constraint on the Λn interaction.
- Theoretically, the possibility of a $^3_\Lambda$n bound state seems remote. However, results from the JLAB tritium experiment (see the previous talk by Pandy) suggest a possible near-threshold structure.
- See Pandy *et al.*, Phys. Rev. C **105**, L051001 (2022) for details of the experiment and analysis.
- In addition to a possible Λnn resonance, two other structures were observed at higher energies; these were interpreted as possible ΣNN resonances.
- The narrower structure closer to the ΣNN threshold is the focus of our interest today. Pandy *et al.* suggest it could be a $\mathrm{T} = 1$ resonance based upon a calculation by Harada and Hirabayshi [Phys. Rev. C **89**, 054603 (2014)]. We suggest that $\mathrm{T} = 0$ is just as likely.

Is there possibly a T = 2 [*e.g.*, $\Sigma^- nn$] bound state or resonance?

- In 1987 Garcilazo demonstrated using rank-one separable potentials that no T = 2, ΣNN bound state or resonance should exist. See H. Garcilazo, J. Phys. G **13**, L65 (1987).
- In 1994 Stadler *et al.* confirmed that there was little possibility of either a ΣNN, T = 2 bound state or narrow resonance based upon a Jülich one-boson exchange potential. See A. Stadler and B. F. Gibson, Phys. Rev. C **50**, 512 (1994). In addition, this result demonstrated the usefulness of separable potential calculations regarding low energy properties of 3-body systems.
- However, it was noted that continuum Faddeev calculations were needed to address the existence of T = 0 and T = 1 resonance states.

Faddeev calculations for the T = 0 and T = 1 ΣNN continuum resonances

- In 1993 Afnan *et al.* found a near-threshold T = 0 resonance while exploring Λd elastic scattering. This was based upon a separable potential model of the ΛN-ΣN coupled channel interaction. See I. R. Afnan and B. F. Gibson, Phys. Rev. C **47**, 1000 (1993).
- Later, in 2007, Garcilazo *et al.*, utilizing a separable potential approximation to a chiral constituent quark model of the hyperon-nucleon interaction, concluded that the T = 0 and T = 1 spin-1/2 channels of the ΣNN system were the only attractive channels. Only the T = 1 channel was sufficiently attractive to support a near-threshold resonance. See H. Garcilazo, T. Fernandez-Carames, and A. Valcarce, Phys. Rev. C **75**, 034002 (2007).
- We have performed additional calculations using the code in the reference above, which was developed for $^3_\Lambda$H investigations; see I. R. Afnan and B. F. Gibson, Phys. Rev. C **41**, 2787 (1990). I will come back to the ΣNN results, but briefly we find T = 0 and T = 1 resonances that are unlikely sufficiently separated to be distinguished experimentally.

Additional ΣNN resonance information

- In 1992 Barakat *et al.* reported a null result in a ^{3}He(K$^-$, π^+) in-flight K$^-$ experimental search at BNL for a ΣNN resonance. See M. Barakat and E. V. Hungerford, Nucl. Phys. **A 547**, 157c (1992).
- In 2014 Harada *et al.* performed a distorted wave impulse approximation calculation that agreed with the BNL ^{3}He(K$^-$, π^+) result of no resonance. However, their model results indicated that one should see a T = 1 resonance in ^{3}He(K$^-$, π^-). See T. Harada and Y Hirabayashi, Phys. Rev. C **89**, 054603 (2014).
- As noted previously, we had in 1993 found that there should be a T = 0, ΣNN resonance, and Garcilazo *et al.* published in 2007 model results suggesting that there should exist a T = 1 resonance situated near the ΣNN threshold.

Comparison of Faddeev calculation results

- The 1993 s-wave separable potential T = 0 pole position is 75.46 - 8.81i MeV, which lies near the ΣNN threshold at 77 MeV (in our model).
- The Garcilazo *et al.* separable approximation to the chiral quark model found: (i) The (T,J) = (1,1/2) resonance lies close to the Σd threshold. (ii) The (0,1/2) channel does not support a resonance.
- Our recent calculation finds for the T = 1 pole position 76.81 - 6.32i MeV, closer to the ΣNN threshold than our T = 0 pole.
- The Garcilazo *et al.* model result is more sophisticated in that it includes a tensor force in both the NN and the YN interactions. When we include a tensor force in the NN interaction, the resulting poles move slightly closer to the ΣNN threshold, but their relative positions remain unchanged.

Summary

The primary conclusions from our model calculation are (i) that one should see both a T = 0 resonance as well as a T = 1 resonance in the ^{3}H(e,e$'$ K$^+$)ΣNN spectrum near that threshold and (ii) that the two resonances will likely reside too close to one another to be easily separated experimentally.

THANK YOU FOR YOUR ATTENTION!