A Possible Observation of Λnνn Continuum Structure and a Bound ΣNN State using the (e e’K⁺) Reaction

Update on E12-17-003 Experiment
Data Taken: October 31 to November 26 2018
Hall A/C summer Joint Collaboration Meeting
Jefferson Lab
July 16, 2020

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Outlines:

- Physics motivation
- Single arm data analysis
- VDC tracking problem
- Coincidence data analysis
- Analysis result
- Summary
Physics Motivation:

- The YN and YY interactions are difficult to produce as compared to NN interactions.
- Limited data exists for the YN interaction.
- An interaction data does not exist.
- Significant charge symmetry breaking is reported in case of $A = 4$ isospin mirror pair of hypernuclei.
- The HypHI experiment indicated the existence of either a resonance or the bound state.
Hall A was not Optimized for the Experiment:

- Hall A with tritium target aimed to search for the $\Lambda_{nn}$ resonance or the bound state as indicated by HypHI experiment. However, the system was not optimized for this experiment.

- The electron arm was at very large angle $\theta_{e'} = 13.2^\circ$ , produces large $Q^2 = 0.5(GeV/c)^2$ which results low production yield.

- The path length for the hadron arm was too large (~ 26 m) which limits the $K^+$ survival rate ~ 10 %.

- The $\vec{q}(\Lambda)$ is too high ~ 400 MeV/c which gives very small value of $d\sigma/d\Omega$.

- The $K^+$ efficiency of the aerogel detector was very low.

- No cross-section information is available.
Each of the z vertex was optimized with single arm trigger data and then averaged with the coincidence data.

The z vertex resolution of about $\sigma = 4.5$ mm was achieved.

To select the events from the gas region, z vertex ranging from -10 cm to 10 cm was selected.
HRS Angle Reconstruction with Multi-foil Target:

- Achieved acceptable angular resolution.
- The RHRS has more background as the hadrons are punching through the sieve slit and producing secondary hadrons.
• The time resolution of about 370 ps was achieved for a 2 ns CEBAF beam bunch.
• The $K^+$ are cleanly separated from the rest of the hadrons.
• The accidentals are because of the inefficient KID detectors.
The resolution was limited to about 2 MeV is $\sigma$ which was far from our requirement.

The VDC tracking problem at the RHRS for the coincidence events was detected.
After the time jitter correction, both the single and coincidence trigger mode spectrum are in agreement with each other.

Thanks to Dr. Ole Hansen for his great effort to solve the tracking problem.
The momentum calibration is the two dimensional correlation.
There are only three data points to calibrate the momentum matrices.
There is a large kinematic gap between the two $\Lambda$ correlation lines.
The optics quality may not be uniform in the gap region.
The Al data was involved in matrix tune, which has negligible angular dependence.
Al is Considered as Target:

- Z-average > -14 cm & Z-average < -11 cm
- Z-average > 11 cm & Z-average < 14 cm

Gas region

- Al region is selected from both beam entrance and beam exit window and combined together for matrix tune.
After searching the first single state real peak, Al data was involved in tune with $\Lambda$ and $\Sigma^0$ masses.

Other peaks are gradually involve in tune one by one.
- The $\Lambda$ and $\Sigma^0$ landed at their known masses with a separation of 76.94 $MeV/c^2$ (Nominal = 76.96 $MeV/c^2$).
Tritium data was tested for H contamination and found ~ 2% of H was present in the Tritium gas which is consistent with other tritium experiments.
Mass Spectroscopy of $^3_n\Lambda$:

- The first peak which is the possible resonance was expected, however, the statistics is very small to make a definite identification.
- The peak at the higher excitation was not expected, therefore, its origin is unclear.
Mass Spectroscopy with Higher Bins:

- The enhancement at the $\Sigma$ bound region was predicted before and is a possible bound $\Sigma$ hypernuclei.
The experiment demonstrated that by using the tritium target and the (e e’K+) reaction, it is possible to observe the 3 body final state $\Lambda nn$ and $\Sigma NN$ interaction. However, Hall A system need to be optimized for higher statistics.

From this experiment two resonance states of $^3\Lambda n$ and one bound state of $^3\Sigma n$ were observed. However, to make a definite identification, higher statistics are required.

A simulation predicted the intrinsic missing mass resolution of $A = 3$ resonance to be $\sigma = 0.66$ MeV. Thus, the natural width is about 0.55 MeV.

However, due to low statistics the precision does not permit sufficient constrain in determination of the $\Lambda$-n Interaction.

Conclusions:
Thank you
Backup: