Partial Wave Analysis of the Reaction $\mathbf{p + p \rightarrow p + K^+ + \Lambda^*}$

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The ongoing discussion about anti-kaonic nuclear bound states is still far from being solved. Besides various theoretical models, predicting a range of possible width and masses, the experimental quest for this state has also delivered no clear picture up to now.
The HADES collaboration will search for this state in a measured p+p run at E_{kin} = 3.5 GeV. The predicted bound state would be produced in the following reaction:

$$p + p \rightarrow \bar{K}NN + K^+ \rightarrow p + \Lambda + K^+. \qquad (1)$$

Where $\bar{K}NN$ is the kaonic cluster, which is often also called ppK^-. Thus, we aim to reconstruct this bound state in the final state $p + \Lambda + K^+$. In order to understand, if a new state contributed to the reaction one has to understand how the $p\Lambda K^+$ final state is formed in $p + p$ reactions. In fact, it is well known that these three particles can also be produced via the decay of intermediate N^* resonances:

$$p + p \rightarrow N^* + p \rightarrow K^+ + \Lambda + p. \qquad (2)$$

To describe the measured data with help of a model one needs to know the contributing N^* resonances. Additionally their exact production properties, like angular distributions, have to be as well included correctly. In order to model the transition amplitudes from the $p + p$ initial state to the $pK^+\Lambda$ final state we choose the Bonn-Gatchina Partial Wave Analysis (PWA) [1].

To select a data sample, which contains mostly the final state $pK^+\Lambda$, a kinematic fit was applied to the data. The data were compared to an event hypothesis, which demanded that the three particles fulfill energy and momentum conservation. Additionally, the $p + \pi^-$ from the Λ decay had to have an invariant mass close to the nominal Λ mass of 1115.7 MeV/c^2. A measure for the agreement between the event and the hypothesis is the p-value, which is an output of the fit. The event hypothesis was fulfilled, if the p-value from the kinematic fit did exceed 0.01. In this way 13,000 events have been selected with a contamination by wrong events of $\approx 7\%$. This data set is the input for the PWA.

There are seven resonances listed in the PDG that can be possibly produced in our energy regime and have a known decay branching into $K^+ + \Lambda$. These are $N(1650)$, $N(1710)$, $N(1720)$, $N(1875)$, $N(1880)$, $N(1895)$ and $N(1900)$. Several solutions were tested in the PWA, which include different combinations of N^* resonances and non-resonant production of $pK^+\Lambda$. An example of a good solution is shown in Figures 1 and 2. Here, the invariant mass distribution of ΛK^+ and Λp is displayed. The PWA

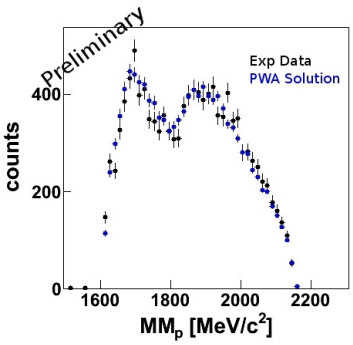


Figure 1: ΛK^+ inv. mass. Data with a PWA solution

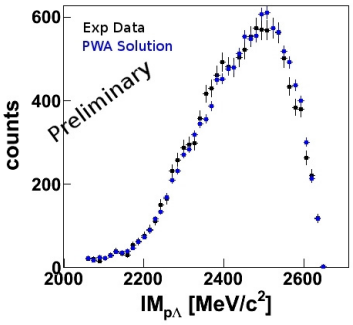


Figure 2: Invariant mass of Λp compared to a PWA solution

solution, that is overlaid to the data inside the acceptance of the HADES spectrometer, contained as input $N(1650)$, $N(1710)$, $N(1720)$, $N(1875)$, $N(1895)$ and several non-resonant waves of $pK^+\Lambda$ production. One can see that this particular solution yields an excellent description of the experimental distribution. The data show no significant yield exceeding the PWA solution. According to these results, the next step of this work is to include the ppK^- wave in the PWA fit and determine an upper limit for the production cross section of a kaonic cluster, produced in $p + p$ collisions at 3.5 GeV kinetic beam energy.

References

[1] A.V. Anisovich, V.V. Anisovich, E. Klempt, V.A. Nikonov and A.V. Sarantsev Eur. Phys. J. A 34, 129152 (2007).

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