PROCEEDINGS OF SCIENCE

Exclusive pKΛ production in p+p reactions

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This report shows a proposed analysis strategy to investigate the existence of the smallest kaonic bound state the so-called ppK^- in p+p reactions at a beam kinetic energy of 3.5 GeV, measured with the HADES experiment. First comparisons between experimental data and simulations show a clear mismatch that calls for employment of more sophisticated models to describe the reaction $p+p \to p+K^+ + \Lambda$.

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[†]A footnote may follow.

1. Motivation

This work is motivated by the prediction of the existence of nuclear kaonic bound states. Within a coupled channel approach based on chiral dynamics a strong attractive $\bar{K}$N interaction was found in the $I = 0$ channel by constraining the model to low energy K^{-}p scattering data. Such an attractive interaction could form the basis of nuclear clusters bound together by anti-Kaons. A first phenomenological approach, predicted a deeply bound ppK^{-} system with a binding energy of $B = 48\ MeV$ and a width of about $\Gamma = 61\ MeV/c^2$ [1]. Recent calculations within a chiral interaction model do on their part obtain binding energies of the smallest kaonic cluster ppK^{-} in the order of B$\approx 20\ MeV$ and widths of $\Gamma \approx 40\ MeV/c^2$ [2][3]. These predictions are not consistent with the published experimental data [4][5], showing two signals interpreted as the ppK^{-} with a binding energy of more than 100 MeV. Indeed, these values for the binding energy are not reproducible by theoretical calculations, neither phenomenological ones nor the ones based on chiral dynamics. Additionally the measured width of the signals differs by 50 MeV. This discrepancy requires new experimental measurements. We have recorded $1.2{\cdot}10^9$ events from a p+p reaction with a proton beam of a kinetic energy of 3.5 GeV impinging on a hydrogen target with the **H**igh **A**cceptance **D**i-**E**lectron **S**pectrometer (HADES) [6] at GSI. Out of this statistic we aim to find hints or upper limits for the production of the smallest kaonic bound state the ppK^{-}. Note that this is the same reaction, as studied in [5] but at a higher beam kinetic energy.

2. Towards a solid ppK^{-} analysis

In the collected statistic we have managed to reconstruct the exclusive reaction where a K^{+} and a Λ are produced together with a proton. This final state can be produced via the following three ways:

$$p + p \rightarrow p + K^{+} + \Lambda \tag{2.1}$$

$$p + p \rightarrow N^{*+} + p \quad \llcorner\!\!\rightarrow K^{+} + \Lambda \tag{2.2}$$

$$p + p \rightarrow ppK^{-} + K^{+} \quad \llcorner\!\!\rightarrow p + \Lambda \tag{2.3}$$

The kinematic observables, which are considered in this analysis, strongly depend upon the production mechanisms due to the exclusive kinematics of two body production and decays, as already investigated in [7]. A p$K^{+}\Lambda$ final state produced via process (2.2) can not be described by process (2.1), where the particles are produced directly, only according to available phase space. Previous publications have reported indications which explain the production of the p$K^{+}\Lambda$ final state mainly via process (2.2) [8][9]. It is thus our main concern to obtain a proper description of the process leading to the p$K^{+}\Lambda$ final state. The ppK^{-} cluster is still of a hypothetical nature and if it exists it is expected to be produced with a cross section considerably smaller than the dominating sources (2.1) and (2.2).

2.1 Aimed procedure for a description of the p$K^+\Lambda$ final state

Not only the contribution of (2.1) and (2.2) to the measured final state is an unknown but also the masses and widths of the N^{*+} resonances, decaying into $K^+\Lambda$, have to be determined. On top of this neither of the three particles will be produced with an isotropic distribution in the production angles in the center of mass system (CMS) as well as the decay products in the N^{*+} rest frame. These anisotropic cross sections have to be modeled as well. Two procedures are at our disposal: first we find a model-independent way to obtain an acceptance correction for the measured data to be able to observe possible anisotropies in the particle-production directly. Then the simulations can be modeled according to the measured differential distributions. These simulations have to be adapted to the data in an iterative procedure. Second we perform a partial wave analysis of the measured statistic, within the HADES acceptance, to extract the composition of waves that is fitting best to the experimental yield. For this purpose we intend to use the partial wave analysis framework of the Bonn-Gatchina group [10]. In both cases the solution should describe the kinematics of the three measured particles completely. Suited observables to analyze the agreement between the obtained model and the data are hereby for example the momenta and CMS production angles of the particles. Figures 1-3 show these observables for the kaon, proton and Λ respectively. The data are obtained after an exclusive event selection of the p$K^+\Lambda$ production. Shown with the data are simulations containing process (2.1), produced only according to phase space. The comparison shows that such simulations fail to reproduce the experimental distributions.

Apart from the proper modeling of the single particle properties the correlation of particles among each other needs to be constructed as well. Therefore differential cross section or invariant mass observables have to be studied in detail, like it is done in [8].

3. Estimation of an upper limit of the ppK$^-$ production cross section

If one achieves a satisfactory description of the experimental data via the simulations two scenarios can be considered. In case of a sufficiently large cross section and a narrow ppK^- width a direct excess of data compared to the model might be seen in the pΛ invariant mass spectrum. If this state does not exist or the cross section is very small a χ^2 fit to the data, adding a new signal to the simulations or the partial wave analysis input, can be performed. By monitoring the χ^2 value of the agreement between model and experimental data a 99% confidence level of excluding a certain scenario can be achieved. In this way upper limits of a production cross section, under the assumption of varying masses and widths of the ppK^- might be obtained. An example for such an analysis can be found in the search for low mass di-baryon states in a $p\Lambda$ decay, as performed by the HIRES collaboration [11].

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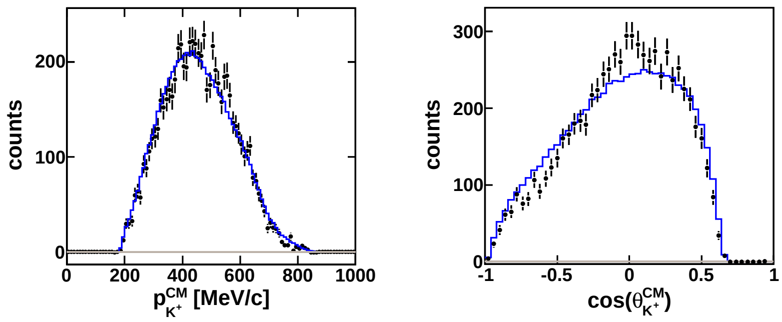

Figure 1: Momentum and cosθ distribution of the K^+ in the CM system. Black points show the measured data, the blue line shows simulations of process (2.1)

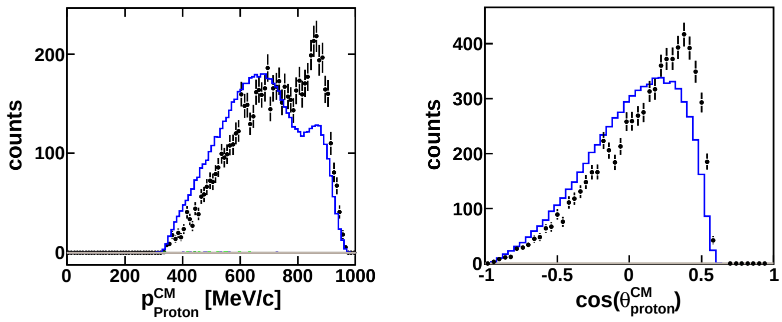

Figure 2: Momentum and cosθ distribution of the proton in the CM system. Black points show the measured data, the blue line shows simulations of process (2.1)

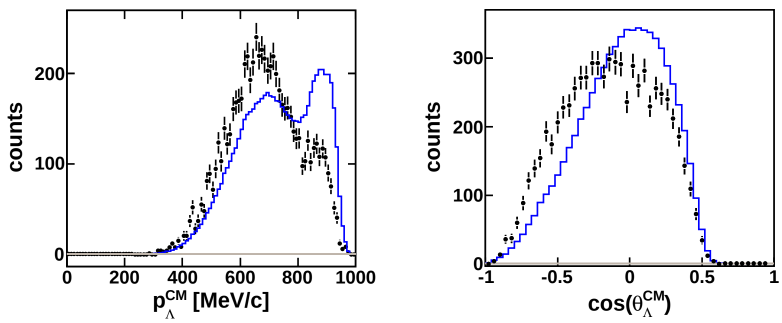

Figure 3: Momentum and cosθ distribution of the Λ in the CM system. Black points show the measured data, the blue line shows simulations of process (2.1)

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