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New boundaries for the "ppK^-" production in p+p collisions

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Abstract. The HADES collaboration has searched for the anti-kaonic nuclear cluster "ppK^-" in p+p collisions by its decay into $p\Lambda$. In the course of this analysis several cross checks had to be performed. This report discusses two examples thereof. In one test it was checked whether the presence of background events could introduce a bias on the applied partial wave analysis. The second item discussed here is the extraction of the total $pK^+\Lambda$ production cross section necessary to derive the absolute upper limit on the "ppK^-" production cross section.

1 Introduction

The anti-kaonic cluster "ppK^-" was investigated by the HADES Collaboration in p(3.5GeV)+p reactions [1]. Since no signal has been found in the data an upper limit on its production cross section was determined. To perform this analysis, we have selected the exclusive $pK^+\Lambda$ final state ($\Lambda \rightarrow p\pi^-$) in two different regions of the detector acceptance. These two data-sets are named HADES and WALL data-set, according to the detectors where the decay proton from the Λ was reconstructed. They have a purity of ≈93% and ≈85%, respectively. The major source of background comes from the misidentification of kaons and a small contamination from the $pK^+\Sigma^0$ final state. Since investigations have shown that the direct production of $pK^+\Lambda$ is not a good model to describe the data [2, 3], we have utilized the Bonn-Gatchina partial wave analysis framework [4, 5], which includes also N* production ($\rightarrow K^+\Lambda$), to model this reaction [1, 6]. This work is meant to describe one aspect of quality assurance of the PWA fit and present the extraction of the $pK^+\Lambda$ production cross section.

2 Cross Checks

To test the reliability of the PWA, several checks have been performed. One important check was performed for instance to show that the fit of the N* contributions is not biased by an accidental presence of kaonic cluster signal events in the data-set, as shown in Ref. [6].

The second check, which is discussed in this work, deals with the question if the remaining background in the statistic (no real $pK^+\Lambda$ events) strongly modifies the fit result. Since the background and real $pK^+\Lambda$ events are non-separable, the PWA fit uses both events to determine the correct solution. In case the background would be distributed systematically different as compared to real $pK^+\Lambda$

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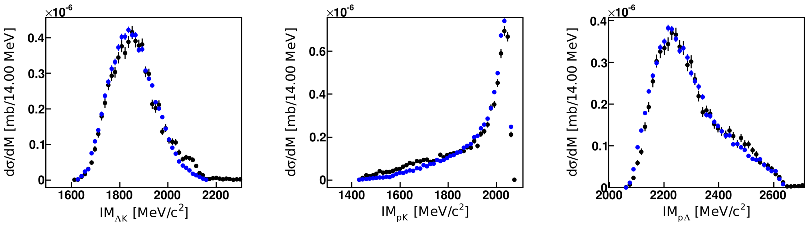

Figure 1. Two-particle mass distributions of the $pK^+\Lambda$ events. Black dots show the measured event distributions and the blue dots display the PWA solutions that was extrapolated into the WALL data-set acceptance.

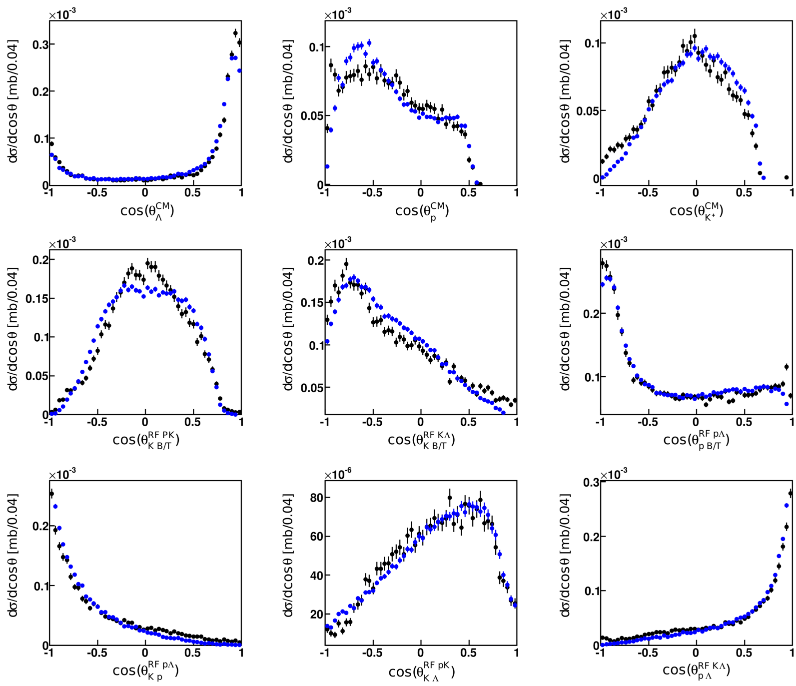

Figure 2. Angular distributions of the $pK^+\Lambda$ events. Black dots show the measured event distributions and the blue dots display the PWA solutions that was extrapolated into the WALL data-set acceptance.

events the kinematics in the PWA solution would be modeled wrong. To exclude this malfunction in the procedure, first only the HADES statistic was fed into the PWA fit. This solution was then extrapolated into the WALL acceptance region to check the agreement with the WALL data-set. As this second data-set covers a completely different phase space region and contains an independent fraction of background events, this is a good test of the stability of the result and the functionality of the PWA.

Figures 1 and 2 present the extrapolated PWA solution in the WALL acceptance (blue dots) together with the measured data (black dots). Although, these events were not used as input for the fit, the experimental data can be qualitatively very well described by the unbiased PWA solution. There are minor deviations in CM and Gottfried-Jackson angles (first and second row of Fig. 2) but no systematic mis-description of the data. The most crucial problem that could occur is that the background content deteriorates the description of the $p\Lambda$ invariant mass spectrum, since this distribution is the sensitive observable to search for the new signal of the "ppK^-" bound state. As visible in Fig. 1, the measured $p\Lambda$ invariant mass is described very well by the PWA solution. This means that the presence of background events in the PWA fit does not bias the fit to a wrong description of the data.

3 Total $pK^+\Lambda$ Production Cross Section

The upper limit on the "ppK^-" production cross section in p(3.5 GeV)+p reactions, that is reported in Ref. [1] and was extracted with help of the PWA solution, is given in % of the total $pK^+\Lambda$ production cross section for this collision system. In order to obtain an absolute value of the "ppK^-" upper limit, the $pK^+\Lambda$ production cross section has to be extracted from the data. To do so, the measured data have to be corrected for losses due to efficiency and acceptance. The model taken for the acceptance correction was the PWA solution with the best fit result. To obtain the correction, the PWA solution was evaluated in each investigated observable in 4π and after the full scale analysis (in the acceptance). Each bin of the experimental distribution of the observable was corrected by the ratio of the two PWA histograms. The corrected event distributions are shown in Figs. 3 and 4 with the systematic uncertainty displayed by the gray boxes. This uncertainty was obtained by correcting the data with slightly different PWA solutions, which nonetheless all describe the experimental observables well. The histogram entries additionally contain a global uncertainty of 7% due to the normalization of measured events to a cross section. In some figures deviating bins are shown in the inlets.

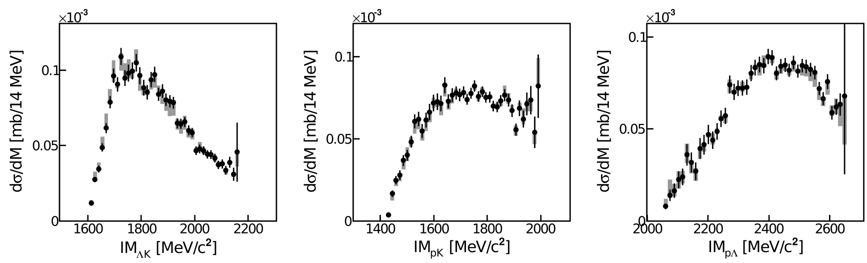

Figure 3. Two-particle mass distributions of the $pK^+\Lambda$ events. Black dots show the event distributions corrected for acceptance and efficiency losses. The gray boxes indicate the systematic uncertainty.

To extract the $pK^+\Lambda$ production cross section the bin entries were summed. If statistic was missing due to acceptance holes (Fig. 3 and panels a)-c) of Fig. 4), the total cross section was extrapolated with help of the model value. This extraction was done independently for each of the 12 displayed observables. Further, each observable was analyzed with four different acceptance corrections due to four different models. Depending on the investigated observable and the used correction model the extracted total production cross section varies. It ranges from 35.29±0.33 μb to 41.67±1.09 μb. As nominal value the average cross section of all 12 variables, corrected with the best PWA solution, was taken. The final result thus reads: $\sigma_{pK^+\Lambda}$(3.5 GeV)= $38.12 \pm 0.43^{+3.55}_{-2.83} \pm 2.67 - 2.86\ \mu$b. The errors are the statistical uncertainty, the systematic uncertainty, the global uncertainty of the normalization, and the background error. The result purely stems from the HADES data as the efficiency of the forward WALL was not known. The total $pK^+\Lambda$ sample is not background free and therefore 2.86 μb are attributed to the background yield and need to be subtracted to obtain the pure $pK^+\Lambda$ cross section.

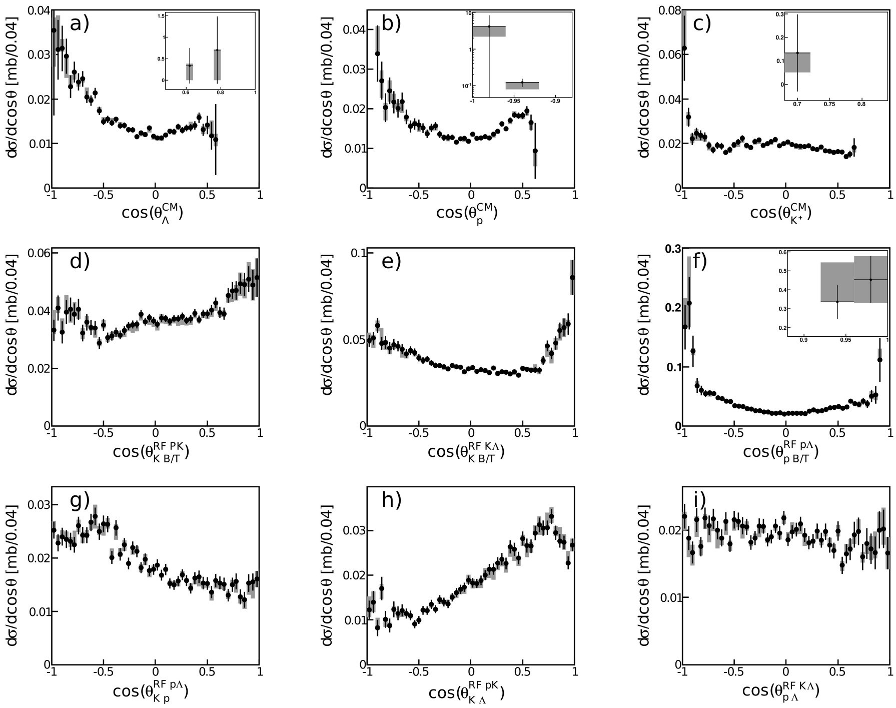

Figure 4. Angular distributions of the $pK^{+}\Lambda$ events. Black dots show the event distributions corrected for acceptance and efficiency losses. For details about the observables see Ref. [1].

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