Chapter 145
Low-Energy K^- Nucleon/Multi-nucleon Interaction Studies by AMADEUS

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Abstract The AMADEUS collaboration aims to provide new experimental constraints to the K^-N strong interaction in the regime of non-perturbative QCD, exploiting low-energy K^- hadronic interactions with light nuclei (e.g. H, ^{4}He, ^{9}Be and ^{12}C). The low-momentum kaons ($p_K \sim 127$ MeV/c) produced at the DAΦNE collider are ideal to explore both stopped and in-flight K^- nuclear captures. The KLOE detector

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is used as an active target, allowing to achieve excellent acceptance and resolutions for the data. In this work the results obtained from the study of $\Lambda\pi^-$ and Λp correlated production in the final state are presented.

145.1 Introduction

The theoretical investigation of the low-energy K^-N interaction predicts, in the energy region below the K^-N threshold, a sufficiently attractive interaction to form a bound state in the isospin I = 0 channel [1, 2].

In [3–7] the I = 0 $\Lambda(1405)$ is interpreted as a pure $\bar{K}N$ bound state, this leads to the prediction of deeply bound kaonic nuclear states. According to Chiral models [8–12] the $\Lambda(1405)$ emerges as a superposition of two states, as a consequence the K^-N interaction is much less attractive, which implies the prediction of only slightly bound kaonic nuclear states.

The experimental investigation of the K^-pp bound state properties in K^- induced reactions is strongly biased by the competing K^--multi-nucleon absorption processes, leading to the same final states (see e. g. [13, 14]). In [15, 16] a complete characterisation of the K^- two-, three- and four-nucleon absorptions (2NA, 3NA and 4NA) was performed for the first time in the Λp and $\Sigma^0 p$ final states exploiting low-energy K^- captures on a solid ^{12}C target. In particular, in [15] the corresponding low-energy cross sections are measured, these represent a crucial ingredient for the determination of the in-medium K^- optical potential [17, 18]. In Sect. 145.2 a brief summary of the analysis [15] is given.

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The experimental investigation of the $\Lambda(1405)$ properties is also challenging. The resonance line-shape is found to depend on both the production mechanism and the observed decay channel. Moreover in K^- induced reactions the non-resonant contribution to the final state $\Sigma\pi$ production has to be also taken into account. In Sect. 145.3 a brief summary of the results obtained in [19] is given, which could give important informations on the underlying $\bar{K}N$ interaction models.

The described analyses refer to a sample of 1.74 fb^{-1} integrated luminosity, collected by the KLOE collaboration [20] during the 2004/2005 data campaign. Low-energy K^-s are produced at the DAΦNE collider [21], from the phi-meson decay nearly at-rest, with a momentum of about 127 MeV/c. The K^- captures, at-rest and in-flight, on the materials of the KLOE detector, used as an active target, are investigated.

145.2 K^- Multi-nucleon Absorption Cross Sections and Branching Ratios in Λp and $\Sigma^0 p$ Final States

The possible existence of the K^-pp bound state can be investigated in low-energy K^- induced reactions by reconstructing the decays to $\Lambda(\Sigma^0)$p.

Recently, $\Lambda(\Sigma^0)$p decay modes were investigated by the AMADEUS collaboration in K^{-12}C absorption [15]. These studies allowed to perform the first comprehensive measurements of two, three and four nucleon absorption branching ratios (BRs) and cross sections for low-momentum kaons in Λp and Σ^0p channels. The BR of the Σ^0p direct production in K^- 2NA quasi free interaction is found to be greater than the corresponding Λp production, contrary to what is expected by comparing the pure phase spaces. This gives important indications on the underlying three-body interaction. The Λp spectra are entirely interpreted in terms of K^- multi-nucleon absorption processes, an eventual contribution due to the intermediate formation of a K^-pp bound state completely overlaps with the K^- 2NA in this channel, hence the corresponding yield is not extracted.

145.3 Resonant and Non-resonant $Y\pi$ Transition Amplitudes Below the $\bar{K}N$ Threshold

In the investigation of the $\Lambda(1405)$ properties, produced through the K^-p mechanism in light nuclear targets, two biases have to be taken into account. The first bias is the energy threshold imposed by the absorbing nucleon binding energy (for K^- capture at rest on ^{4}He the $\Sigma\pi$ invariant mass threshold is about 1412 MeV, while for ^{12}C it is about 1416 MeV). In order to access to the $\bar{K}N$ sub-threshold region corresponding to the $\Lambda(1405)$ high-mass predicted pole (about 1420 MeV), K^-N absorption in-flight has to be exploited. For a mean kaon momentum of 100 MeV/c, the $\Sigma\pi$ invariant mass threshold is shifted upwards by about 10 MeV.

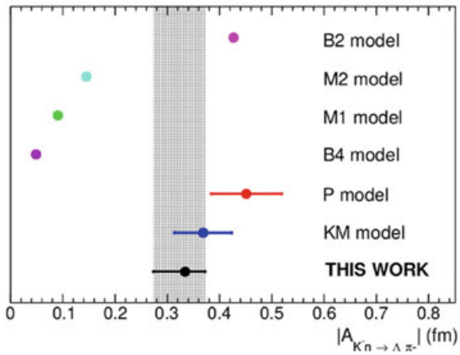

Fig. 145.1 Modulus of the measured non resonant $K^-n \to \Lambda\pi^-$ transition amplitude compared with theoretical calculations, see details in the text. Figure is adapted from [19]

The second bias is related to the non-resonant $K^-N \to Y\pi$ reaction, which was experimentally investigated for the first time in the $K^-n \to \Lambda\pi^-$ process, considering K^-n single nucleon absorptions in ^{4}He [19]. In this work the experimentally extracted $\Lambda\pi^-$ invariant mass, momentum and angular distributions were simultaneously fitted in by means of dedicated MC simulations. All the contributing reactions were taken into account: non-resonant processes, resonant processes and the primary production of a Σ followed by the $\Sigma N \to \Lambda N'$ conversion process. The simulations for non-resonant/resonant processes were based on the results of [22]. The analysis allowed the extraction of the non-resonant transition amplitude modulus $|A_{K^-n\to\Lambda\pi^-}|$ (33 ± 6) MeV below the $\bar{K}N$ threshold which is found to be $0.334 \pm 0.018\ stat\ ^{+0.034}_{-0.058}\ syst$ fm. The result of this analysis (with combined statistical and systematic errors) is shown in Fig. 145.1 and compared with the theoretical predictions (see [23] (P), [24] (KM), [25] (M1,M2), [26] (B2,B4)) rescaled for the $K^-n \to \Sigma\pi$ transition probabilities. This measurement can be used to test and constrain the S-wave $K^-n \to \Lambda\pi^-$ transition amplitude calculations.

145.4 Conclusion

In this work the low energy interaction between K^- and nucleons/nuclei in light nuclear targets are investigated with the aim to better understand the non-perturbative quantum chromodynamics QCD in the strangeness sector. Studies of low-energy K^- captures on a solid carbon target result in a complete characterisation of the two-, three- and four-nucleon absorptions in the Λp and $\Sigma^0 p$ final states (BRs and cross sections). The characterization of the non-resonant $K^-N \to Y\pi$ production was investigated for the first time for K^-n single nucleon absorption in ^{4}He. The result is crucial for the investigation of the $\Lambda(1405)$ characteristics.

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