HYPERNUCLEAR PRODUCTION INDUCED BY IN-FLIGHT K AND $\pi^*$

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The development in treating K- and $\pi$-induced hypernuclear production reactions is reviewed, including the application of DWIA to the $(K^-, K^+)$ reaction to produce $\Xi^-$. After summarizing the conventional DWIA treatment without spin-dependence, we discuss the calculational method of strength functions up to the continuum. Finally the process is reformulated starting from the elementary amplitudes with the spin-flip component as well as the spin-nonflip one. The new treatment is shown to be powerful and the emphasis is put on the production of polarized hypernuclei, which provides a useful spectroscopic tool for the weak-decay mechanism.

1. Introduction

The complementary roles of different reactions to disclose many-sided aspects of hypernuclei have been recognized. The $(K, \pi)$ and $(\pi, K)$ reactions constitute such a typical example. Recently, in addition to the singles experiment, the coincidence measurements of the hypernuclear production and decays have started, and the hypernuclear spectroscopy in its genuine sense is now being explored. The data from new hypernuclear production and decay experiments are providing novel information on the structure of hypernuclei, which discloses dynamical aspects as well as the static properties of the baryon many-body system with strangeness.

The first aim of this article is to clarify the basic properties of in-flight $(K^-, \pi^\pm)$ and $(\pi^\pm, K^+)$ hypernuclear production reactions by demonstrating the typical experiments and the theoretical explanations and predictions. The merits and characteristics of these reactions are discussed. The success of the conventional DWIA treatment for these reactions leads to an application to the in-flight $(K^-, K^+)$ reaction for the $\Xi$-hypernuclear production.

Secondly, we summarize the development of the theoretical treatment of these reactions: (i) In Sect. 2 we present the results calculated in DWIA within the standard approximation in which only the bound state hypernuclear wave functions are employed and the spin-flip component of the elementary process is neglected. (ii) Then, in Sect. 4, the DWIA treatment is improved so as to describe the

*) Dedicated to our distinguished collaborator, Professor Jan Žofka (1943–1991), to the memory of his inspiration in hypernuclear physics and his wide, friendly activities in our community.
quasi-free strength in the continuum as well as the bound-state strengths. This improvement has been achieved by adopting the Kapur-Peierls method with proper outgoing boundary condition. (iii) On the other hand, the advanced treatment starting with the elementary amplitudes which consist of both the spin-nonflip and spin-flip components will be presented in Sect. 5.

The third purpose of this paper is to present new estimates of production rates of polarized hypernuclei with mixed wave functions. The hypernuclear polarization was studied theoretically for the first time in Refs. [1,2] in which, however, the actual calculations were limited to the absorption-based polarization without any spin-flip interaction introduced. After the reanalysis [3] of the \( \pi^- p \to K^0 \Lambda \) elementary data, the spin-nonflip and spin-flip amplitudes became available in a convenient form. The polarized hypernuclear productions in the \( (\pi^+, K^+) \) reaction [4,5] and in the \( (K^-, \pi^-) \) reaction [6] are estimated so far with simple p-h wave functions. In this paper, the configuration-mixed wave functions are employed and the depolarization processes due to \( \gamma^- \) and particle-emissions are taken into account.

In Sect. 2 the conventional DWIA formulae for the in-flight reactions are given before discussing the basic aspects of the \( (\pi^+, K^+), (K^-, \pi^-) \) and \( (K^-, K^+) \) reactions in the following. Section 4 is devoted to the unified treatment of bound and continuum strengths within the framework of the Kapur-Peierls method. The correct estimate of the quasi-free hyperon production will be emphasized, as the strength is generally much greater than that leading to the hyperon-bound states. In Sect. 5, first the production cross section is reformulated on the basis of the elementary amplitudes with the spin-flip component. Then the typical results are discussed for \( (\pi^+, K^+) \) and \( (K^-, \pi^-) \) reactions at the incident momenta larger than 1 GeV/c. The conclusion is given in Sect. 6.

2. Basic aspects of \( (\pi^+, K^+) \) and \( (K^-, K^+) \) reactions

2.1 Conventional DWIA treatment for the in-flight reactions

In the conventional way of the impulse approximation neglecting the spin dependence, the two-body reaction \( t \)-matrix in the nuclear medium is replaced by the free-space \( t \)-matrix with the same incident momentum. Then the DWIA cross section is factorized into the elementary cross section and the 'effective nucleon number' \( N_{\text{eff}} \) as

\[
\frac{d\sigma(\theta)}{d\Omega_L} = \xi \left[ \frac{d\sigma(\theta)}{d\Omega_L} \right]_{\text{KN} \to \Lambda \pi} N_{\text{eff}}(i \to f; \theta),
\]

where \( \xi \) is the kinematical factor arising from the two-body to many-body frame transformation. Here we give the expressions for the \( (K^-, \pi^-) \) reaction, but they are also applicable to \( (\pi^+, K^+) \) and \( (K^-, K^+) \) with self-evident replacements. The transition operator \( \hat{O}^{(K^-, \pi^-)} \) is given by the relevant meson distorted waves as

\[
\hat{O}^{(K^-, \pi^-)} = \int d^3\vec{r} \chi_{\pi^-}^*(\vec{k}_\pi, a_{\pi}) \chi_{K^-}^*(\vec{k}_K, \vec{r}) \sum_{\nu=1}^A U_-(\nu) \delta(\vec{r} - \frac{M_c}{M_A} \vec{r}_\nu),
\]