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Kinematical effects in electroproduction of hypernuclei

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Abstract. On the example of electroproduction of ${}^{12}_{\Lambda}$B we show effects in the cross section caused by various choices of the momentum of the initial proton. We have found that the effects are quite noticeable, mainly for small kaon angles. This extention of our model calculations beyond the frosen-proton approximation represents an important improvement of theoretical predictions.

1 Motivation

Studying spectra in electroproduction of hypernuclei provides important information about details of the effective ΛN interaction, mainly on its spin-dependent part. A reasonable analysis of experimental data, however, requires a good knowledge of the reaction mechanism. One of uncertainties in the DWIA calculations of the cross sections is the Fermi motion of the initial (target) proton. Here we will discuss effects due to various choices of the proton momentum in the optimal factorization approximation. Assuming non-zero values of the proton momentum improves on previous calculations [2] where the zero momentum (the frozen-proton approximation) was used.

2 Calculation of the cross section and the results

The cross sections for electroproduction of hypernuclei are calculated in the impulse approximation. Details on the calculation can be found in Ref. [1], here we mention only some facts concerning the extention of our previous model calculations presented in Ref. [2].

In the optimal factorization approximation the Fermi averaging integral is factorized by assuming the elementary amplitude at an effective (non zero) proton momentum. To this end, the two-component form of the elementary amplitude was extended also by including dependence on the proton momentum. The remaining parts of the electroproduction amplitude, the radial integrals and one-body density matrix elements (OBDME) were treated as in the previous calculations [2].

The kaon momentum is calculated from the energy conservation. In the elementary amplitude, we use the kaon momentum calculated from the energy conservation in the elementary vertex (2-body), the amplitude is therefore on-energy-shell, but the kaon momentum used in the radial integrals and in a kinematical factor at the cross section [1] is calculated from the overall (many-body) energy conservation. This hybrid scheme with two different kaon momenta was also used in the previous calculations [1].

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Using a new form of the elementary amplitude with a non-zero proton momentum, however, allows to consider an optimum value of the proton momentum which fulfils the energy conservation both in the 2-body and many-body systems. Then the calculation proceeds with one common value of the kaon momentum and the elementary amplitude is on-energy-shell.

We consider the following values of the effective proton momentum (p_p):
a) p_p = 0, the frozen-proton approximation;
b) p_p equal to momentum transfer between photon and kaon and, therefore $p_\Lambda = 0$ (the frozen-Λ approximation);
c) p_p equal to the optimum value (the optimum on-shell approximation).

In the figure we show the angular dependence of the electroproduction cross sections for excited states 1^+, 2^+, and 3^+ of ${}^{12}_{\Lambda}$B. The results are for the three selected proton momenta given above calculated in PWIA with the elementary amplitude BS3 [3]. The nucleus-hypernucleus structure (OBDME) is described in the Shell-model calculations by John Millener as in Ref. [2]. Similar results in DWIA and more details on the analysis can be found in [1].

The calculations in the proton and Λ-frozen approximations are done with two different kaon momenta as discussed above, whereas in the optimum on-shell approximation one value of kaon momentum is used. The results differ more for very small kaon angles and the Λ-frozen result is mostly larger than the other results. One can conclude that the differences in PWIA due to the Fermi motion of the proton amount up to about 10–20% for the dominant (3^+) hypernucleus state. Noticeable is also the different ordering of the green (optimum) and red (frosen-proton) curves for the states 1^+ and 3^+ and for 2^+ which is mainly given by selective contributions from the longitudinal part of the electroproduction amplitude [1].

3 Summary and outlook

A general two-component form of the amplitude in electroproduction of kaons on the nucleon was constructed. This new form, which contains a dependence on the proton momentum, allows to extend our calculations beyond the frozen-proton approximation and show effects from a proton Fermi motion in the target nucleus. In the PWIA calculations, the effects amount to about 10–20% for the most strongly populated states and they are larger at small kaon angles. We suggest using the optimum on-shell approximation, which makes kinematics (the kaon momentum) more consistent.

We plan to continue our analysis by assuming the sensitivity of the cross sections to various descriptions of the nuclear and hypernuclear structures.

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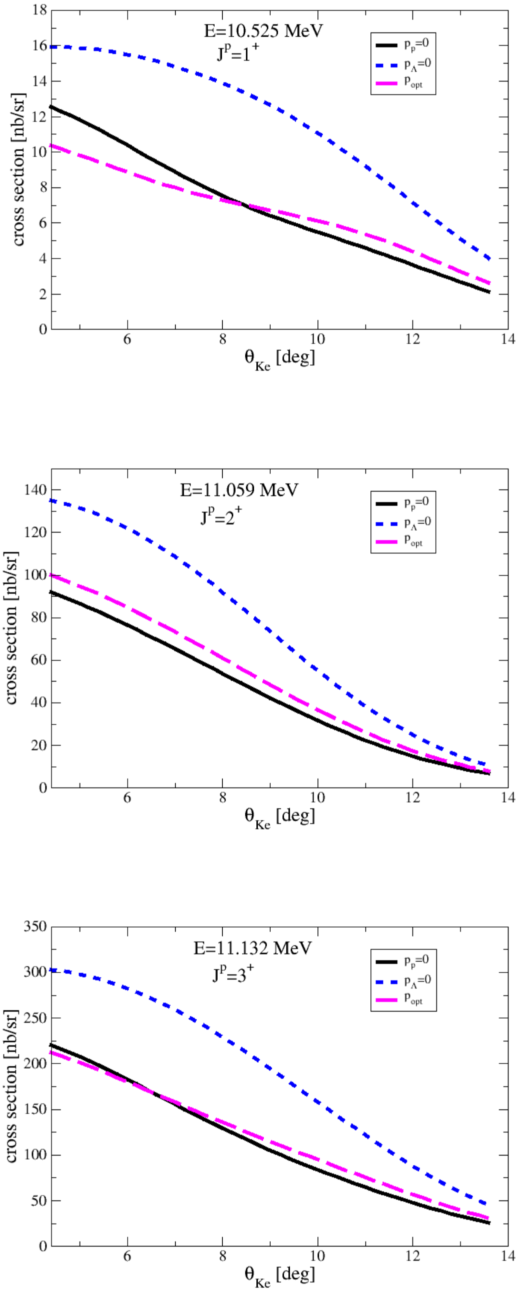

Figure 1. Angular dependence of the electroproduction cross sections induced by virtual photons for three excited states of ${}^{12}_{\Lambda}$B with the energy E and spin-parity J^p.