Report on the doctoral thesis of Daria Denisova
“Electroproduction of Hypernuclei“
Petr Bydžovský

The thesis deals with a study of various aspects in model calculations of the cross section in electroproduction of hypernuclei. The work was motivated by a need of having a reliable formalism suited for an analysis of available experimental data as well as for preparation of future experiments. The well established formalism should also include estimation and understanding uncertainties due to various model approximations and input data in the calculation. Investigating a structure and other properties of hypernuclei is an important part of contemporary nuclear physics as it extends our knowledge of the baryon-baryon interactions.

The cross sections are calculated in the distorted-wave impulse approximation (DWIA) where the elementary-production amplitude is evaluated at an effective proton momentum. In majority of previous calculations this momentum was taken to be zero (the frozen-proton approximation) as in this special case the elementary amplitude obtains a relatively simple form. To estimate effects due to using non-zero values of the effective momentum, a general two-component form of the elementary amplitude was derived in the thesis and used to show dependence of the cross sections on various values of the proton momentum. These effects from Fermi motion of the initial proton inside the target nucleus were studied using two elementary amplitudes with different energy and spin dependence. Moreover, other effects from using different schemes of determination of the kaon momentum were also studied and an optimum on-shell approximation suggested. The effects were demonstrated on the angle and energy dependent cross sections for various excited states of 12^B_Lambda.

Another important part of the reaction dynamics is the kaon distortion which is included in the eikonal approximation. Effects from the distortion were studied in electroproduction of light (p-shell) and medium-mass (sd-shell) hypernuclei. It was shown that the distortion is very important component part of the calculation reducing the cross sections which improve agreement with the experimental data. The reduction is more pronounced for heavier hypernuclei and for the states with the lambda hyperon in lower single-particle orbits.

The nucleus and hypernucleus structure, which determine a strength of the single-particle transitions, is included via the one-body density matrix elements (OBDME) and corresponding proton and lambda-hyperon single-particle wave functions. These important input ingredients in the calculation are obtained from many-particle calculations using an in-medium effective hyperon-nucleon interaction. Influence of using different many-particle approaches (shell model and Tamm-Dancoff) and forms of the Nijmegen-F effective hyperon-nucleon interaction was studied suggesting that the TD approach can be used for a reasonable description of the p-shell and sd-shell hypernuclei. Using this approach predictions of the excitation spectra in electroproduction of 40^K_Lambda and 48^K_Lmabda were provided for the planned experiments at Jlab in U.S.A. It was shown that the excitation spectra are quite sensitive to a form of the hyperon-nucleon interaction, given by the value of the Fermi momentum.

The cross sections in electromagnetic production of hypernuclei calculated in previous decades were mainly performed assuming the frozen-proton approximation and for photoproduction, i.e, with the real photon. However, as the experiments are carried out for virtual photons and the energy resolution is steadily improving, a more realistic and precise electroproduction calculations are needed to analyse the data. The advanced formalism used in this work, i. e., mainly with the modern elementary amplitudes evaluated at a non-zero proton momentum and with consistent use of the single-particle wave functions and OBDME in a sufficiently large model space, can contribute to studying electroproduction of a wide range of hypernuclei.

The thesis is divided into four sections. The first one includes a short review on the history and methods of studying hypernuclei. A comparison is also made of hypernuclus production performed on the hadron and electron beams.

The formalism and important components in computing the cross sections are described in the second section. First, it is shown how the unpolarised cross sections are calculated from the reduced amplitude. Then the formula for the reduced amplitude is derived leaving some unimportant details in the appendix A. Kinematics of the reaction and description of the computational schemes are given in subsection 2.3. Calculating important ingredients in the formula for the reduced amplitude, the elementary amplitude, the radial integrals and the OBDME, is described in the subsections 2.4 – 2.6.

Results and their discussion is given in section 3. First, the Fermi-motion and other kinematical effects in electroproduction of 12^B_Lambda are presented and discussed and a dynamical selection rule is formulated explaining a similarity of the results for groups of hypernucleus states. In subsection 3.2. influence of the kaon distortion is demonstrated. In the last subsection, impact of using various many-particle approaches and forms of the hyperon-nucleon interaction is shown and discussed.

Conclusions are drawn in section 4.

More technical issues on deriving the many-particle matrix element and the new two-component forms of the elementary amplitude (the CGLN-like and the spherical form) are given in appendix A - C. Performing the numeric calculations is described in appendix D.

The thesis was carefully written using original results. The work is based on two papers in Phys. Rev. C and the results were also successively presented at international conferences (MESON and HYP) and at seminar in INP in Řež. The numerical results presented in the figures and tables of the thesis were obtained solely by the student and they are mostly supplemental to the published results. The student demonstrated that she understands well the problematic of hypernucleus electroproduction and can obtain her own results utilising the complex formalism and the input ingredients provided by her colleagues, such as OBDME, the elementary-production amplitude, the kaon-nucleon scattering amplitude, and the single-particle wave functions. She was also able to tackle more technical problems in the demanding calculations, for example, the numeric integration and Dirac algebra. She also took an active part in deriving the new two-component form of the elementary amplitude.

In conclusion, the student has contributed to the obtained results, which are new and important for a future analysis of the data, and has certificated that she is able to present her results. Therefore, I recommend that the thesis is let to be defended and after a successful defence the student was awarded the degree PhD.

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RNDr. Petr Bydžovský, CSc.
the supervisor of the thesis