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Review of the Ph.D. Thesis of Vitalii Urbanevych
titled: Photodisintegration and Pion Absorption in Two- and Three-Nucleon Systems:
A Testing Ground for the SMS Chiral Model

The doctoral thesis of Vitalii Urbanevych is devoted to studies of the quality of nucleon-nucleon potentials with respect to their ability to describe a few-nucleon processes. These processes include photodisintegration of deuteron, triton, and helium-3, as well as the pion absorption by few body systems. Unfortunately, I could not find information concerning the publications, on which the thesis is based. In the list of references, at the end of the thesis, I managed to find only one paper coauthored by Vitalii Urbanevych. The paper has been published in Physical Review C and features 10 authors. Vitalii Urbanevych is listed in second place, which suggests that his contribution was dominating.

The thesis contains four chapters and a bibliography. The first chapter contains an introduction to the problem of the construction of nucleon-nucleon potentials. Author focuses mainly on a very popular potential known as AV18 and the family of potentials originating from the chiral effective field theory. He discusses the problem of regularization and cutoff dependence associated with the usage of these potentials.

In the second chapter, Vitalii Urbanevych presents the formalism applied in the thesis to describe photodisintegration and pion absorption processes. The first part of this chapter is devoted to the theoretical approach, used in the description of a few nucleon systems, which include Lippmann-Schwinger framework and Faddeev equations. Author starts with the case of 2N bound states, presenting, as a test, deuteron binding energy as a function of nucleon-nucleon potentials, obtained at various orders of expansion generated within chiral effective field theory. Subsequently, he discusses 2N scattering states and 3N bound and scattering states. Then he presents the method of description of nucleon-deuteron scattering states and, finally, the pion absorption process. The last section is devoted to the presentation of various sources of errors, that are generated, when evaluating observables. Since the author focuses on the interactions based on chiral expansion, the factor influencing the accuracy of the results is related to the order of truncation. Throughout the thesis, Vitalii Urbanevych consequently uses chiral interaction up to the fourth order. The second source of errors is related to the cutoff parameter. Author uses the so-called SMS (semilocal momentum-space regularized potential) potentials with four values of the cutoff parameter. Other sources of theoretical uncertainties, that are briefly discussed in the thesis, include: the presence of a single nucleon current, relativistic effects, uncertainties of potential free parameters, and numerical methods.

The next chapter forms the core of the thesis. Author presents results, discusses their stability with respect to various errors and, if experimental data are available, analyzes sources of discrepancy between theory and experiment. It begins with the description of deuteron photodisintegration. The evaluated differential cross sections indicate that both Av18 and N4LO potentials provide results of essentially the same accuracy. Moreover, potentials obtained in lower orders seem to converge, and author concludes that higher order expansion will not produce any significant improvement of presented results. Subsequently, author discusses the results for the selected polarization observables for two photon energies: 30 MeV and 100 MeV. Introducing vector and tensor analyzing powers, he investigates their sensitivity to various orders of chiral interaction. The results

obtained at lower photon energy seems to be stable with respect to truncation errors and the cutoff parameter. For higher photon energies the quality of the results are visibly poorer.

In the next section, Vitalii Urbanevych investigates photodisintegration of heavier systems, namely, helium-3 and triton. For the former, two final channels are considered: three body breakup and the deuteron+proton channel, whereas for Triton, only three body breakup is taken into account. Author evaluated the differential cross section for these processes for all orders of chiral interaction up to the fourth order and four values of the cutoff parameter. The final part of this chapter is devoted to studies of pion absorption on deuteron, triton and helium-3. The results have been obtained for NN potentials generated within N2LO, N3LO, N4LO and N4LO+ expansions, and for four values of the cutoff parameter: 400, 450, 500, 550 MeV. Vitalii Urbanevych investigates, for example, differential absorption rates and concludes that the differences between N3LO and N4LO potentials are negligible.

Finally, the conclusions are described in the fourth chapter. I found the most important conclusion to be, that chiral SMS interaction in fourth order, represents essentially the quality, which at the current experimental precision, need not to be corrected by including higher order terms. However, the inclusion of a two-nucleon current seems to be crucial for the accurate reproduction of experimental data on photodisintegration. Author also did not notice an importance of three-body forces in the description of the processes, except for the pion absorption on Triton. He indicates also that Coulomb interaction, which was neglected in this research, should eventually be incorporated in the theoretical framework.

The thesis is clearly written, and in my opinion, represents an interesting material for those who would like to learn about the quality of the state-of-the-art nuclear forces in the description of photodisintegration and pion absorption processes in few nucleon systems. Although the thesis do not contain any startling results, it documents a very thorough and important analysis of experimentally accessed observables and the stability of the results with respect to the errors generated by theoretical description. Therefore, the thesis represents an invaluable source of information on the quality of NN forces.

I did not find any mistakes and all figures are clearly described. What I missed, however, in the thesis, is the additional material in the form of appendices, that would describe the following issues:

1. Definition of vector and tensor analyzing powers and their relation to differential cross section in formula 3.2.
2. The definition of photon asymmetry introduced on page 38.
3. The setup for three-body breakup processes introduced on page 56. Although there is a reference to the paper, it would significantly increase the readability of the thesis, if the scheme was discussed in the appendix.

Despite these minor shortcomings, in my opinion, the thesis fulfills all requirements that have to be met by PhD theses and therefore I herewith request to admit Vitalii Urbanevych to further stages of PhD procedure.