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REVIEW

for the dissertation by **Tkachenko Alessya Sergeevna**
"Phase shift analysis of nuclear processes with the spin structure 1+1/2, 1+1, 1/2+3/2 and astrophysical applications",
submitted for the degree of Doctor of Philosophy (PhD)
in the specialty 6D060500 – "Nuclear physics"

Ms. A. S. Tkachenko's Ph.D. dissertation "Phase shift analysis of nuclear processes with the spin structure 1+1/2, 1+1, 1/2+3/2 and astrophysical applications", is devoted to the interesting and hot topic in nuclear physics related to the development of the scattering phase shift formalism for the high-spin nuclear processes relevant for the astrophysical applications and the theoretical description and the analysis of the $^3He(^2H,\gamma)^5Li$ and $^{10}Be(n,\gamma)^{11}Be$ radiative capture processes in the framework of the modified potential cluster model (MPCM).

The dissertation consists of Introduction, four Sections, Conclusion, Appendix, a list of references and is organized in the following way. The introduction provides an overview of the topic of the dissertation, the purpose and the objective of the research. Section 1 presents the scattering phase shift formalism for the high-spin nuclear processes and the obtained analytical expressions for the partial and total differential cross sections for elastic scattering of nuclear particles for channels with a spin value of 1/2, 1, 3/2, 2 and 5/2. The framework of the MPCM or the description of cluster-cluster systems relevant for astrophysical applications is presented in Section 2. Astrophysical processes $^3He(^2H,\gamma)^5Li$ and $^{10}Be(n,\gamma)^{11}Be$ at law energies are considered in Section 3 and 4, respectively. At the end of the dissertation the general conclusions of the performed research were described, and research beyond this dissertation is discussed.

Let us review the dissertation step by step, following each Section. In Section 1 Ms. Tkachenko presents analytical expressions for differential cross sections and independent partial amplitudes of elastic scattering of nuclear particles for channels with a spin value of 1/2, 1, 3/2, 2 and 5/2. The independent partial amplitudes are calculated considering the spin-orbit splitting for arbitrary orbital angular momentum l. The analytical expressions allow one to carry out full phase shift analysis using experimental data of differential cross sections for processes with channel spins 1/2, 1, 3/2, 2 and 5/2. In particular, analytical expressions are obtained for processes with spin-1/2 – spin-3/2, spin-1/2 – spin-1, spin-1/2 – spin-2 and spin-1 – spin-3/2. Furthermore, the classification of spin-dependent interaction potentials and the relationship of parameters in the laboratory system and in the center of mass system is also given in Section 1. Section 2 presents the principles and formalism for constructing the potentials of discrete and continuous spectra within the framework of MPCM and the potentials for the description of $^3He(^2H,\gamma)^5Li$ and $^{10}Be(n,\gamma)^{11}Be$ radiative capture are obtained

The next two Sections of the dissertation in my opinion are very interesting, and are focused on the application the developed formalism for astrophysical processes $^3He(^2H,\gamma)^5Li$ and $^{10}Be(n,\gamma)^{11}Be$, respectively. In Section 3 Ms. Tkachenko presents the results obtained with the potentials which were parametrized in the previous Section 2 for the total cross section, the astrophysical *S*-factor, the *S*-factor screening effects, and the rate of the $^3He(^2H,\gamma)^5Li$ radiative capture reaction. Calculations of the total cross sections, astrophysical *S*-factor, and reaction rates have been performed for $^3He(^2H,\gamma)^5Li$ radiative capture within the modified potential cluster model with forbidden states, which follow from the classification of the orbital cluster states according to Young diagrams. Numerical data and corresponding parametrizations cover the energy range up to 5 MeV and temperature range $T_9<10$. An updated compilation of detailed data for the reaction $^3He(^2H,\gamma)^5Li$ is presented.

In Section 4 as the first step Ms. Tkachenko processes the experimental data and classification for the $E1$ transition capture and then presents detailed calculations of the $^{10}Be(n,\gamma)^{11}Be$ reaction characteristics, using the framework of the modified potential cluster model, succeeds in correctly describing the available experimental data for neutron radiative capture on ^{10}Be total cross sections at low, astrophysical and thermal energies. It is important to mention that the present calculations are based on new experimental data for Coulomb dissociation. The energy range is extended from 10^{-5} to 10^4 keV for the theoretical cross sections, covering a range of temperatures between 0.01 and 10 T_9. The role of the halo asymptotics of the extra-core neutron in ^{11}Be is also considered. The theoretical cross-sections have been calculated from the thermal energy 10.0 meV up to 10.0 MeV and approximated by a simple function of energy, which can be used for calculation of the cross-sections at energies less than 10 eV. The parametrization of the reaction rates for the process $^{10}Be(n,\gamma)^{11}Be$ are obtained in an analytical form that is convenient for future calculations of different scenarios involving element synthesis in *r*-processes.

The topic of the dissertation is interesting enough and very timely due to current experimental and theoretical research in nuclear astrophysics to explain the primordial nucleosynthesis in the Universe. In this work, a technique related to the MPCM has been extensively used, expressions for the differential cross sections and independent partial amplitudes enable phase shift analyses for different integer and half-integer channel spins are obtained which allow one to find corresponding phase shifts using experimental data for a nucleon-nucleus and nuclear-nuclear reaction cross sections and detailed theoretical description and analysis of the astrophysical processes $^3He(^2H,\gamma)^5Li$ and $^{10}Be(n,\gamma)^{11}Be$ is presented. This work is clearly communicated, the dissertation is written in a clear and understandable style and the supplementary information presented in the Appendix allows one to comprehend the text of the dissertation. The references are relevant to the subject and show the recent status and past developments in the subject of research. The figures, schemes, and tables are shown properly as well. Ms. Tkachenko clearly demonstrates a high level of professionalism and deep knowledge of the subject. To sum up, the dissertation represents a good level of scientific work with scientific novelty and an extensive range of research.

During the research Alessya Tkachenko has established herself as a competent young scientist, able to independently solve the scientific problems assigned to her. This is confirmed by publications in high-ranking prestigious scientific journals, such as Nuclear Physics A and Astroparticle Physics, and presentations at international scientific conferences, including International Conference on Few-Body Problems in Physics (FB22), Caen, France.

To conclude, the reviewed dissertation fulfills all requirements posed on the dissertation of Doctor of Philosophy, and the research conducted by Ms. Alessya Tkachenko and presented in the dissertation "Phase shift analysis of nuclear processes with the spin structure 1+1/2, 1+1, 1/2+3/2 and astrophysical applications", is on the cutting edge in low energy nuclear physics. In my opinion Alessya Tkachenko undoubtedly deserves to be granted the degree of Doctor of Philosophy (PhD) in the specialty 6D060500 – "Nuclear physics".

Foreign scientific supervisor

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