

**REVIEW**  
**of the official reviewer for dissertation work**  
**of Valiolda Dinara Salavatkyzy on the theme «Coulomb breakup of exotic nuclei by quantum-mechanical approach»**  
**presented for the degree of Doctor of Philosophy (PhD) in the specialty «6D060500-Nuclear physics».**

№	Criteria	Eligibility (one of the options must be checked)	Justification of the position of the official reviewer
1.	The topic of the thesis (as of the date of its approval) corresponds to the directions of development of science and/or state programs	1.1 Compliance with priority areas of science development or government programs:  1) The thesis was completed within the framework of a project or target program financed from the state budget (indicate the name and number of the project or program) 2) <u>The thesis was completed within the framework of another state program (indicate the name of the program)</u> 3) The dissertation corresponds to the priority direction of the development of science, approved by the Higher. Scientific and Technical Commission under the Government of the Republic of Kazakhstan (indicate the direction)	Results of the study presented in the dissertation work of Valiolda D.S. are fully compliant with priority areas of science.  Dissertation of Valiolda D.S. corresponds to the priority direction of development of science "Scientific research in the field of natural sciences". This work was supported by JINR-Republic of Kazakhstan Cooperation Program order №435 paragraph 3, Grant of the Plenipotentiary Representative of the Government of the Republic of Kazakhstan at JINR 01-3-1136-2019/2022, «Investigation of the Coulomb breakup of the halo nuclei in a non-stationary quantum approach».
2.	Importance for science	The work makes a significant contribution to science, and its importance is well disclosed	Results presented in the thesis have theoretical significance within the corresponding area of research. The importance of obtained results is well disclosed.
3.	The principle of independence	Self-reliance level: 1) High:	I assume a sufficient level of independence of the thesis' studies,

		2) Medium; 3) Low; 4) No independence	which is compliant with the requirements. The results of studies are confirmed by publications in international journals with high impact factors.
4.	The principle of inner unity	4.1 Justification of the relevance of the thesis: 1) <u>Justified</u> ; 2) Partially justified; 3) Not justified.	The theoretical study of halo nuclei within the framework of the non-stationary quantum-mechanical approach is relevant in connection with planning experiments on the study of light nuclei in radioactive beams, for instance in connection with the research program at HIE-ISOLD (CERN) and ReA12 (MSU). This and further justifications are supported by the publication of research results in such high-rank journals like European Physical Journal A, Physics of Particles and Nuclei letters. In general, the relevance of the dissertation work is fully disclosed, and also substantiated in detail by the author.
		4.2 The content of the thesis reflects the topic of the thesis: 1) <u>Reflects</u> ; 2) Partially reflects; 3) Does not reflect	The content of the dissertation reflects the topic of the dissertation. Starting with the introduction, three sections and the conclusion, the thesis reflects the content of the obtained results. The dissertation contains 62 list of references, as well as 34 figures and 11 tables.
		4.3. The purpose and objectives correspond to the topic of the thesis: 1) <u>correspond</u> ;	In the thesis, the author clearly formulated the purpose and

		<p>2) partially correspond; 3) do not correspond</p>	<p>objectives of the study, which corresponds to the topic of the dissertation.</p>
		<p>4.4 All sections and provisions of the thesis are logically interconnected: 1) <u>completely interconnected</u>; 2) the interconnection is partial; 3) there is no interconnection</p>	<p>The provisions and all sections of the thesis are interconnected with each other.</p>
		<p>4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions: 1) <u>there is a critical analysis</u>; 2) partial analysis; 3) the analysis does not represent one's own opinions, but quotes from other authors</p>	<p>The new solutions proposed by the author (principles, methods) are argued and evaluated in comparison with the results of theoretical works of other authors. Since in the previous calculations only two bound states of the <math>^{11}\text{Be}</math> nucleus were taken into account (the ground state <math>1/2^+</math> and the first excited state <math>3/2^-</math>), it is assumed that taking into account low-lying resonances will improve the theoretical description of the experimental data on the cross section for the breakup reaction <math>^{11}\text{Be} + ^{208}\text{Pb} \rightarrow ^{10}\text{Be} + n + ^{208}\text{Pb}</math> at intermediate energies and explain the appearance of visible peaks in the energy range 1.23, 2.78, and 3.3 MeV, which corresponds to the position of the peaks of resonances <math>5/2^+</math>, <math>3/2^-</math> and <math>3/2^+</math>.</p>
5.	Scientific novelty principle	<p>5.1 Are the scientific results and provisions new? 1) <u>completely new</u>; 2) partially new (25-75% are new); 3) not new (less than 25% are new)</p>	<p>The scientific results and provisions to be defended in this thesis are new, in particular: a) The low-lying resonant states (<math>5/2^+</math>, <math>3/2^-</math> and <math>3/2^+</math>) of the <math>^{11}\text{Be}</math> were</p>

			accuracy of the semiclassical approach with linear trajectories of the projectile was also demonstrated for the $^{11}\text{Be}$ breakup cross sections up to 30 - 20 MeV/nucleon. It is shown that this approach is also useful at lower energies, where, however, a more adequate description is provided by the quantum-quasiclassical approach.
		5.3 Technical, technological, economic or management decisions are new and reasonable: 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The obtained results on the basis of numerical calculations are consistent with the qualitative study of the obtained differential equations, as well as with studies conducted earlier by other authors. The main conclusions and provisions of this work are justified.
6.	The validity of the main findings	All main conclusions are based on scientifically significant evidence or well-grounded (for qualitative research and areas of training in the arts and humanities)	Based on the results of the dissertation work, 6 printed works were published, 4 of that were published in journals included in the database indexed by SCOPUS scientometric databases, 2 - in the journals included in the list recommended by the Committee for Quality Assurance in the Sphere of Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan.
7.	The main provisions for the defense	It is necessary to answer the following questions for each provision separately: 7.1 Is the provision proven? 1) proven;	Provision №1: An account of the low-lying resonance states of $^{11}\text{Be}$ describes the

		<p>2) rather proven;  3) rather not proven;  4) not proven  7.2 Is it trivial?  1) yes;  2) no  7.3 Is it new?  1) yes;  2) no  7.4 Application level:  1) narrow;  2) medium;  3) wide  7.5 Is it proven in the article?  1) yes;  2) no</p>	<p>experimental data on the breakup reaction <math>^{11}\text{Be}+^{208}\text{Pb}\rightarrow^{10}\text{Be}+n+^{208}\text{Pb}</math> cross sections at 69 MeV/nucleon with the accuracy of 1-2% and explains the appearance of visible peaks at energies of 1.23, 2.78, 3.3 MeV, which correspond to the positions of the <math>5/2^+</math>, <math>3/2^-</math> and <math>3/2^+</math> resonances, respectively.  7.1 Proven  7.2 No  7.3 Yes  7.4 Narrow  7.5 Yes  Provision №2:  The breakup cross sections of the halo nucleus <math>^{11}\text{Be}</math> on a heavy (<math>^{208}\text{Pb}</math>) target at low collision energies (30-5 MeV/nucleon), demonstrate a visible peak due to the <math>5/2^+</math> resonant state (<math>E_r=1.23</math> MeV).  7.1 Proven  7.2 No  7.3 Yes  7.4 Narrow  7.5 Yes  Provision №3:  The differences between the linear and curvilinear (realistic) trajectories of the projectile in the analysis of the breakup reaction <math>^{11}\text{Be}+^{208}\text{Pb}\rightarrow^{10}\text{Be}+n+^{208}\text{Pb}</math> is about several percent in the energy range 30-20</p>
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			<p>MeV/nucleon, for 10 MeV/nucleon the discrepancy is 10% and reaches a value of more than 20% at 5 MeV/nucleon, which exceeds the effect of nuclear interaction.</p> <p>7.1 Proven 7.2 No 7.3 Yes 7.4 Narrow 7.5 Yes</p>
8.	The principle of reliability Reliability of sources and information provided	<p>8.1 Choice of methodology - is justified or the methodology is described in sufficient detail 1) yes; 2) no</p> <p>8.2 The results of the thesis were obtained using modern methods of scientific research and methods of processing and interpreting data using computer technologies: 1) yes; 2) no</p> <p>8.3 Theoretical conclusions, models, identified relationships and patterns have been proven and confirmed by experimental research (for areas of training in pedagogical sciences, the results have been proven on the basis of a pedagogical experiment): 1) yes; 2) no</p>	<p>All calculations and the choice of methodology specified in the dissertation work are described in detail.</p> <p>To obtain the results in the thesis, modern scientific research methods were used, with the use of the Wolfram Mathematica and Fortran 90 software. The Coulomb breakup of the halo nuclei is studied numerically, by solving the time-dependent Schrödinger equation on an angular Lagrange and quasi-uniform radial grid.</p> <p>The author fully substantiated the theoretical conclusions and results of the studied models, confirmed the identified relationships and patterns by comparing them with the results of other authors. The obtained results have been compared with experimental data available at 69 and</p>

			72 MeV/nucleon and with existing alternative theoretical calculations of other authors at 20 and 30 MeV/nucleon.
		8.4 Important statements are confirmed by references to current and reliable scientific literature	The main statements are confirmed in all sections by using links to the available scientific literature.
		8.5 Used literature sources are sufficient for a literature review	The list of references includes 62 references in English and Russian, among which many recent publications in high-rank journals can be found, which are sufficient for a literary review.
9	Practical value principle	9.1 The thesis has theoretical value: 1) yes; 2) no	The presented thesis is of theoretical importance, it is devoted to one of the currently popular problems of the theoretical physics. Theoretical significance of the study: exotic nuclei are one of the most intensively studied objects in modern few-nucleon nuclear physics. The theoretical study of halo nuclei within the framework of the non-stationary quantum-mechanical approach is relevant in connection with planning experiments on the study of light nuclei in radioactive beams.

		<p>9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice:</p> <p>1) yes; 2) no</p>
		<p>9.3 Are the practice suggestions new?</p> <p>1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)</p>
10.	The quality of writing and design	<p>Academic writing quality:</p> <p>1) high; 2) average; 3) below average; 4) low.</p>

In this dissertation, a numerical method for solving the non-stationary Schrödinger equation is well described, the work is quite laborious, the breakup reaction of  $^{11}\text{Be}$  halo nucleus on a heavy ( $^{208}\text{Pb}$ ) target was investigated in a wide energy range. There are comparisons with experimental data and with some theoretical calculations. Nevertheless I would like to recommend considering the breakup for other reactions, for example for a light target. Will your theoretical approach work for such reactions and could you include resonant states of  $^{11}\text{Be}$  there? This comment has a recommendatory character and does not diminish the quality of the obtained results.

#### Conclusion on the possibility of awarding the degree of Doctor of Philosophy (PhD), Doctor in profile

On the whole, the dissertation work of Valiolda Dinara Salavatkyzy on the theme «Coulomb breakup of exotic nuclei by quantum-mechanical approach» performed at a high scientific level, is a completed independent research work in content and design meets the requirements of the Committee for Control in the Field of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan to PhD dissertations, and its author Valiolda Dinara Salavatkyzy, undoubtedly deserves to be awarded the degree of Doctor of Philosophy (PhD) in the specialty «6D060500-Nuclear physics».

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