

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	<p>1.1 Compliance with priority areas of science development or government programs:</p> <p>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)</p> <p>2) The thesis was completed within the framework of another state program (indicate the name of the program)</p> <p>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)</p>	<p>Results of the study presented in the dissertation work of Valiolda D.S. are fully compliant with priority areas of science.</p> <p>Dissertation of Valiolda D.S. corresponds to the priority direction of development of science "Scientific research in the field of natural sciences".</p> <p>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 ».</p>
2.	Importance for science	The work makes a significant contribution to science, and its importance is well disclosed	Theoretical significance of the study: of 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

		<p>approach is relevant in connection with planning experiments on the study of light nuclei in radioactive beams. Results presented in the thesis have theoretical significance within the corresponding area of research. The importance of obtained results is well disclosed.</p>
3.	<p>The principle of independence</p>	<p>In the framework of the dissertation research, the author was directly involved in writing and debugging a computational program, processing and analyzing of obtained data, interpreting the results, preparing articles for publication as a full member of the scientific group. The contribution of the applicant to the results of the dissertation is essential. The results of studies is compliant with the requirements and are confirmed by publications in international journals with high impact factors.</p>
4.	<p>The principle of inner unity</p>	<p>The theoretical study of exotic nuclei within the framework of the non-stationary quantum-mechanical approach is important and relevant for the interpretation and planning of future experiments with exotic nuclei, since a substantial lag in the theoretical models from the needs of the experiment in this field. Thus, the obtained results of the dissertation</p>

3.

The principle of independence

Self-reliance level:

- 1) High;
- 2) Medium;
- 3) Low;
- 4) No independence

4.

The principle of inner unity

4.1 Justification of the relevance of the thesis:

- 1) Justified;
- 2) Partially justified;
- 3) Not justified.

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The theoretical study of exotic nuclei within the framework of the non-stationary quantum-mechanical approach is important and relevant for the interpretation and planning of future experiments with exotic nuclei, since a substantial lag in the theoretical models from the needs of the experiment in this field. Thus, the obtained results of the dissertation

		<p>are important for testing existing theoretical models and for the practical application of theoretical calculations in experiments to investigate the breakup of halo nuclei at low-energy radioactive beams.</p> <p>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.</p>
<p>4.2 The content of the thesis reflects the topic of the thesis:</p> <p>1) <u>Reflects</u>;</p> <p>2) Partially reflects;</p> <p>3) Does not reflect</p>	<p>The content of the dissertation fully reflects its topic. All the constituent elements of the dissertation are logically interconnected and structured</p>	
<p>4.3. The purpose and objectives correspond to the topic of the thesis:</p> <p>1) <u>correspond</u>;</p> <p>2) partially correspond;</p> <p>3) do not correspond</p>	<p>The goals of the dissertation is an investigation of low-lying resonances in the Coulomb breakup of ^{11}Be halo nuclei on heavy target (^{208}Pb) from intermediate (70 MeV/nucleon) to low energies (5 MeV/nucleon) within non-perturbative time-dependent quantum-mechanical approach. To achieve these goals, the following objectives were formulated:</p> <p>–to select and analyse parameters of the potentials between the neutron and ^{10}Be core for description of different partial and spin states of the</p>	

		<p>¹¹Be nucleus;</p> <ul style="list-style-type: none"> - to investigate the influence of low-lying resonance states ($5/2^+$, $3/2^-$ and $3/2^+$) to the Coulomb breakup of ¹¹Be nucleus on a heavy (²⁰⁸Pb) target within the semiclassical and quantum-quasiclassical time-dependent approaches; - to study the contribution to breakup of nuclear interaction between projectile and target; - to probe how good is the linear trajectory approach for projectile motion at low beam energies; - to explore the excitation of ¹¹Be in collision with ²⁰⁸Pb target. <p>The purpose and objectives of the thesis are fully corresponded to the topic of the dissertation.</p>
	<p>4.4 All sections and provisions of the thesis are logically interconnected:</p> <ol style="list-style-type: none"> 1) <u>completely interconnected</u>; 2) the interconnection is <u>partial</u>; 3) there is no interconnection 	<p>The thesis is a complete and structured work with a logical sequence and relationships between sections and provisions.</p>
	<p>4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions:</p> <ol style="list-style-type: none"> 1) <u>there is a critical analysis</u>; 2) <u>partial analysis</u>; 3) the analysis does not represent one's own opinions, but quotes from other authors 	<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. The idea of inclusion of low-lying resonances into calculation is improved the theoretical description (with the accuracy of 1-2%) of the experimental data on the cross</p>

		<p>section for the breakup reaction $^{11}\text{Be} + ^{208}\text{Pb} \rightarrow ^{10}\text{Be} + n + ^{208}\text{Pb}$ at intermediate energies, which has not been done before.</p>
<p>5. Scientific novelty principle</p>	<p>5.1 Are the scientific results and provisions new? <u>1) 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:</p> <p>1) An account of the low-lying resonance states of ^{11}Be describes the experimental data on the breakup reaction $^{11}\text{Be} + ^{208}\text{Pb} \rightarrow ^{10}\text{Be} + n + ^{208}\text{Pb}$ 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 $5/2^+$, $3/2^-$ and $3/2^+$ resonances, respectively.</p> <p>2) The breakup cross sections of the halo nucleus ^{11}Be on a heavy (^{208}Pb) target at low collision energies (30-5 MeV/nucleon), demonstrate a visible peak due to the $5/2^+$ resonant state ($E_r=1.23$ MeV).</p> <p>3) The differences between the linear and curvilinear (realistic) trajectories of the projectile in the analysis of the breakup reaction $^{11}\text{Be} + ^{208}\text{Pb} \rightarrow ^{10}\text{Be} + n + ^{208}\text{Pb}$ is about several percent in the energy range 30-20 MeV/nucleon, for 10 MeV/nucleon the discrepancy is 10% and reaches a value of more than 20% at 5</p>

		<p>5.2 Are the dissertation findings new? 1) <u>completely new</u>; 2) <u>partially new</u> (25-75% are new); 3) <u>not new</u> (less than 25% are new)</p> <p>5.3 Technical, technological, economic or management decisions are new and reasonable: 1) <u>completely new</u>; 2) <u>partially new</u> (25-75% are new); 3) <u>not new</u> (less than 25% are new)</p>	<p>MeV/nucleon, which exceeds the effect of nuclear interaction.</p> <p>The main conclusions of the dissertation are completely new and based on a comparative analysis with theoretical and experimental data of other authors.</p>
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)	<p>To solve the problems, the author has developed and adjusted a computer code for the numerical solution of the three-dimensional Schrödinger equation, which was previously used by V.S. Melezhik. At thesis there are new decisions and improvements of the non-stationary approach.</p> <p>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.</p>
7.	The main provisions for the defense	<p>It is necessary to answer the following questions for each provision separately: 7.1 Is the provision proven? 1) <u>proven</u>; 2) <u>rather proven</u>; 3) <u>rather not proven</u>; 4) <u>not proven</u></p>	<p>Provision №1: An account of the low-lying resonance states of ^{11}Be describes the experimental data on the breakup reaction $^{11}\text{Be} + ^{208}\text{Pb} \rightarrow ^{10}\text{Be} + n + ^{208}\text{Pb}$ cross sections at 69 MeV/nucleon</p>

	<p>7.2 Is it trivial? 1) yes; 2) no</p> <p>7.3 Is it new? 1) yes; 2) no</p> <p>7.4 Application level: 1) narrow; 2) medium; 3) wide</p> <p>7.5 Is it proven in the article? 1) yes; 2) no</p>	<p>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 $5/2^+$, $3/2^-$ and $3/2^+$ resonances, respectively.</p> <p>7.1 Proven</p> <p>7.2 No</p> <p>7.3 Yes</p> <p>7.4 Narrow</p> <p>7.5 Yes</p> <p>Provision №2: The breakup cross sections of the halo nucleus ^{11}Be on a heavy (^{208}Pb) target at low collision energies (30-5 MeV/nucleon), demonstrate a visible peak due to the $5/2^+$ resonant state ($E_r=1.23$ MeV).</p> <p>7.1 Proven</p> <p>7.2 No</p> <p>7.3 Yes</p> <p>7.4 Narrow</p> <p>7.5 Yes</p> <p>Provision №3: The differences between the linear and curvilinear (realistic) trajectories of the projectile in the analysis of the breakup reaction $^{11}\text{Be}+^{208}\text{Pb} \rightarrow ^{10}\text{Be}+n+^{208}\text{Pb}$ is about several percent in the energy range 30-20 MeV/nucleon, for 10 MeV/nucleon the discrepancy is 10% and reaches a value of more than 20% at 5</p>
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		<p>MeV/nucleon, which exceeds the effect of nuclear interaction.</p> <p>7.1 Proven</p> <p>7.2 No</p> <p>7.3 Yes</p> <p>7.4 Narrow</p> <p>7.5 Yes</p>
8.	<p>The principle of reliability</p> <p>Reliability of sources and information provided</p>	<p>All calculations and the choice of methodology specified in the dissertation work are described in detail.</p>
	<p>8.1 Choice of methodology - is justified or the methodology is described in sufficient detail</p> <p>1) yes;</p> <p>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:</p> <p>1) yes;</p> <p>2) no</p>	<p>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. For numerical calculations the program code at Fortran 90 were used, the obtained results are processed and illustrated by using of Origin and Mathematica.</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):</p> <p>1) yes;</p> <p>2) no</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 72 MeV/nucleon and with existing alternative theoretical calculations of other authors at 20 and 30</p>

	<p>8.4 Important statements are confirmed by references to current and reliable scientific literature</p> <p>8.5 Used literature sources are sufficient for a literature review</p>	<p>MeV/nucleon.</p> <p>The main statements are confirmed in all sections by using links to the available scientific literature.</p> <p>The list of references includes 62 references, the author refers to the main and new research on the topic of the dissertation work presents both the theoretical methods of other authors and all available experimental data.</p>
9	<p>Practical value principle</p> <p>9.1 The thesis has theoretical value: 1) yes; 2) no</p> <p>9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice: 1) yes; 2) no</p>	<p>The theoretical value of the work is based on the study of the urgent problems of nuclear physics - on the investigation of exotic structures. The numerical approach proposed in the thesis for solving the nonstationary problem is important for the interpretation and planning of experiments on the study of the properties of halo nuclei.</p> <p>The developed computational scheme in this dissertation work opens new possibilities in investigation of Coulomb, as well as nuclear, breakup of exotic nuclei on heavy, as well as, light targets. This theoretical model can potentially be useful for interpretation and planning of low-energy experiments in studying the halo structure of the nuclei. The obtained results at lower energies are important in connection</p>

		9.3 Are the practice suggestions new? 1) <u>completely new</u> ; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	with the research program in this area at HIE-ISOLD (CERN) and ReA12 (MSU). Ideas and developments for the practice of dissertation work are completely new.
10.	The quality of writing and design	Academic writing quality: 1) high; 2) average; 3) below average; 4) low.	The dissertation is written in scientific and technical language, the formulation of provisions and conclusions are complete and reliable.

In the framework of the dissertation work, for a more detailed study of the mechanism of the halo structure, the author included low-lying resonances in various partial and spin states of the ^{11}Be nucleus in the calculation of the breakup cross section in a wide range of beam energies. The contribution of the neutron interaction with the core in the final state and an account of nuclear interaction between the target and projectile to the breakup cross sections were evaluated at low beam energies (5 – 30 MeV/nucleon) and the influence of the curvilinear trajectory for projectile motion is analyzed with decreasing the collision energies. Nevertheless I would like to recommend considering the deformity of the nucleus. It would be interesting to include the deformation of the ^{11}Be in the calculation and study the breakup mechanism. 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 Salavakzy 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 Salavakzy, undoubtedly deserves to be awarded the degree of Doctor of Philosophy (PhD) in the specialty «6D060500-Nuclear physics».

Official reviewer:

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Kabyshev Asset Maratovich

