Few-Body Systems Group (Sector 11) at BLTP, JINR

2011 Annual Activity Report

1 Staff of the BLTP Sector 11 in 2011

1. Vladimir B. Belyaev, Prof., Dr. Sc., Principal Researcher
2. Sabit S. Kamalov, Dr., Senior Researcher
3. Elena A. Kolganova, Dr., Senior Researcher
4. Anastasia V. Malykh, Dr., Researcher
5. Vladimir S. Melezhik, Dr. Sc., Leading Researcher
6. Alexander K. Motovilov, Dr.Sc., Head of Sector
7. Vasily V. Pupyshev, Dr.Sc., Leading Researcher
8. Ivan I. Shlyk, M.Sc., Researcher
9. Evgeni A. Solov'ev, Dr.Sc., Leading Researcher

Artem A. Korobitsin (M.Sc. Student)

Andrei A. Naumkin (M.Sc., Ph. D. Student)

2 Main results

The description of a nucleus as a system of α particles is considered in [SAB] by using a two-variable integrodifferential equation describing A-boson systems. The method is based on the assumption that two-body forces are the dominant ones within the system. This allows the expansion of the A-body wave function in Faddeev components which in turn can be expanded in potential harmonics that result either in a coupled system of differential equations in the hyperradius r or, when projected on the r_{ij} space, in a single two-variable, integrodifferential equation that includes the two-body correlations exactly. The formalism can be readily applied to systems of up to $A \sim 20$. Going beyond this number one encounters increasingly difficult numerical problems stemming mainly from the structure of the kernel in the integral. However, these problems can be eliminated by transforming the equation, when $A \to \infty$, into a new one having a kernel which has a simple analytical form. The transformed equation is employed in [SAB] to perform calculations of nuclei consisting of A α particles. It was found that for the Ali-Bodmer potential the $A = 5$ system, i.e., the ^{20}Ne, is the most stable one while for $A = 10$, i.e., for the ^{40}Ca nucleus, the binding energy has a maximum. Various aspects concerning the formation of $A\alpha$ nuclei are also discussed.

[SAB] S. A. Sofianos, R. M. Adam, and V. B. Belyaev, "α-cluster-model description of nuclei", *Phys. Rev. C* ***84****, 064304 (2011) [6 pages].*

Recent progress on the extraction of electromagnetic properties of nucleon resonance excitation through pion photo- and electroproduction is reviewed in [TDKV]. Cross section data measured at MAMI, ELSA, and CEBAF are analyzed and compared to the analysis of other groups. On this basis, the longitudinal and transverse transition form factors are derived in [TDKV] for most of the four-star nucleon resonances. Furthermore, it is discussed how the transition form factors can be used to obtain empirical transverse charge densities. Contour plots of the thus derived densities are shown for the Delta, Roper, S11, and D13 nucleon resonances.

[TDKV] L. Tiator, D. Drechsel, S. S. Kamalov, and M. Vanderhaeghen, "Electromagnetic excitation of nucleon resonances," *Eur. Phys. J. ST* ***198****, 141–170 (2011).*

Impact of multichannel scattering in harmonic waveguides on the positions and widths of confinement-induced resonances for both isotropic and anisotropic transversal confinement has been analyzed in [MelS]. On the basis of this analysis, a mechanism is established which leads to a splitting of the confinement-induced resonance in the presence of anisotropy which was recently observed in the experiment [Mel2]. Furthermore, d wave resonant scattering of bosons in tightly confining harmonic waveguides has been studied [GMS]. It is shown that the d-wave resonance emerges in the quasi-$1D$ regime as an imprint of a $3D$ d-wave shape resonance. A scaling relation for the position of the d-wave resonance is provided. By changing the trap frequency, ultracold scattering can be continuously tuned from s-wave to d-wave resonant behavior. The effect can be utilized for the realization of ultracold atomic gases interacting via higher partial waves and opens a novel possibility for studying strongly correlated atomic systems beyond s-wave physics.

[MelS] V. S. Melezhik and P. Schmelcher,"Multichannel effects near confinement-induced resonances in harmonic waveguides", *Phys. Rev. A* ***84****, 042712 (2011) [7 pages].*

[Mel2] E. Haller, M. J. Mark, R. Hart, J. G. Danzl, L. Reichsöllner, V. S. Melezhik, P. Schmelcher, and H.-Ch. Nägerl, "Confinement-induced resonances in low-dimensional quantum systems", *Phys. Rev. Lett.* ***104****, 153203 (2010) [4 pages].*

[GMS] P. Giannakeas, V. S. Melezhik, and P. Schmelcher,"Resonant d-wave scattering in harmonic waveguides", *Phys. Rev. A* ***84****, 023618 (2011) [6 pages].*

The concept of Stieltjes integral of an operator-valued function with respect to the spectral measure associated with a normal operator has been introduced in [AM]. Sufficient conditions for the existence of this integral are given and bounds on its norm are found. The results obtained are applied to the Sylvester and Riccati operator equations. Under the assumption that the entry C is a normal operator, that the spectrum of the entry A is separated from the spectrum of C, and that the D is a bounded operator, a representation for the strong solution X to the Sylvester equation $XA - CX = D$ in the form of an operator Stieltjes integral with respect to the spectral measure of C is obtained. By using this result, sufficient conditions are then established for the existence of a strong solution to the operator Riccati equation $YA - CY + YBY = D$ where B is another bounded operator.

[AM] S. Albeverio and A. K. Motovilov, "Operator Stieltjes integrals with respect to a spectral measure and solutions of some operator equations", *Transactions of the Moscow Mathematical Society* ***72****, 45–77 (2011)*.

By assumption, the total proton-hydrogen atom interaction is the sum of the short-range nuclear Reid potential with a soft core and the long-range Thomas-Fermi potential. The quantum-mechanical analysis of the low-energy peculiarities of the phase shifts and cross-section of the proton-hydrogen atom scattering is given in the case of zero total angular momentum. As the result of the calculations performed in the framework of the nonlinear version to the variable phase approach, it is shown in [Pu] that due to the long-range asymptotics of the Thomas-Fermi potential, the cross-section oscillates at low energies but has a finite number of zeros.

[Pu] V. V. Pupyshev, "Proton-hydrogen atom scattering in an effective two-body model", *JINR Preprint P4-2011-123, Dubna, JINR, 2011.*

Recently, the deviations from the OZI rule predictions have been found in many experiments for different types of the hadronic reactions. The reason of a strong violation of the OZI rule proposed is the role of the strange sea quarks in the nucleon. Another indication on the existence of the strange quarks in the nucleon is the measurement of the nucleon magnetic and spin characteristics. Having this in mind it would be interesting to consider the properties of the few-body systems, composed of a φ meson and nucleons under the assumption that the nucleon consists of three light quarks and the φ meson consists of strange quarks only. The assumption like this suggests one to use a simple Van-der-Waals potential, which only includes attraction and describes effectively a multigluon exchange between hadrons. In [BSh], a potential which describes interaction between two φ mesons was introduced for the first time. It reproduces both the mass and width of the $f2(2010)$ resonance in the $\varphi - \varphi$ d-wave decay. To describe the interaction of a φ meson with a nucleon, another Van-der-Waals potential was used. The binding energies of the $\varphi\varphi N$ has been calculated by using the Faddeev differential equations.

[BSh] V. B. Belyaev and I. I. Shlyk, "Few-body meson-nuclear clusters", *Vestnik S.- Peterburgskogo un-ta. Series 4: Physics and Chemistry* ***3****, 110–114 (2011) [Russian].*

The application of a classical approach to various quantum problems — the secular perturbation approach to quantization of a hydrogen atom in external fields and a helium atom, the adiabatic switching method for calculation of a semiclassical spectrum of hydrogen atom in crossed electric and magnetic fields, a spontaneous decay of excited states of a hydrogen atom, Gutzwiller's approach to Stark problem, long-lived excited states of a helium atom recently discovered with the help of Poincaré section, inelastic transitions in slow and fast electron-atom and ion-atom collisions — is reviewed in [Sol]. Further, a classical representation in quantum theory is discussed. In this representation the quantum states are treating as an ensemble of classical states. This approach opens the way to an accurate description of the initial and final states in classical trajectory Monte Carlo (CTMC) method and a purely classical explanation of tunneling phenomenon. The general aspects of the structure of the semiclassical series such as renormgroup symmetry, criterion of accuracy and so on are reviewed as well. In conclusion, the relation between quantum theory, classical physics and measurement is discussed.

[Sol] E. A. Solov'ev, "Classical approach in atomic physics", *Eur. Phys. J. D* ***65****, 331–351 (2011).*

3 Publications

3.1 Journal publications

1. S. Albeverio and A. K. Motovilov, "Operator Stieltjes integrals with respect to a spectral measure and solutions of some operator equations", *Trans. Moscow Math. Soc.* ***72****, 45–77 (2011)*.
2. V. B. Belyaev, "Can water burn?", *Kommersant–Nauka No. 7 (7), 03.10.2011 [Russian].*
3. V. B. Belyaev and A. A. Naumkin, "Approximate treatment of 3-body Coulomb systems: Discrete spectrum", *Few-Body Systems* ***59*** *(2011), 403–405.*
4. V. B. Belyaev and I. I. Shlyk, "Few-body meson-nuclear clusters", *Vestnik S.-Peterburgskogo un-ta. Series 4: Physics and Chemistry* ***3****, 110–114 (2011) [Russian]*.
5. P. Giannakeas, V. S. Melezhik, and P. Schmelcher,"Resonant d-wave scattering in harmonic waveguides", *Phys. Rev. A* ***84****, 023618 (2011) [6 pages].*
6. E. A. Kolganova, A. K. Motovilov, and W. Sandhas, "The ^{4}He trimer as an Efimov system", *Few-Body Systems* ***51*** *(2011), 249–257.*
7. V. S. Melezhik and P. Schmelcher,"Multichannel effects near confinement-induced resonances in harmonic waveguides", *Phys. Rev. A* ***84****, 042712 (2011) [7 pages].*
8. S. A. Sofianos, R. M. Adam, and V. B. Belyaev, "α-cluster-model description of nuclei", *Phys. Rev. C* ***84****, 064304 (2011) [6 pages].*
9. E. A. Solov'ev, "Classical approach in atomic physics", *Eur. Phys. J. D* ***65****, 331–351 (2011).*
10. L. Tiator, D. Drechsel, S. S. Kamalov, and M. Vanderhaeghen, "Electromagnetic excitation of nucleon resonances," *Eur. Phys. J. ST* ***198****, 141–170 (2011).*
11. R. L. Workman, M. W. Paris, W. J. Briscoe, L. Tiator, S. Schumann, M. Ostrick, and S. S. Kamalov, "Model dependence of single-energy fits to pion photoproduction data", *Eur. Phys. J. A* ***47****, 143–155 (2011).*

3.2 Articles in paper collections/conference proceedings

1. A. A. Korobitsin, “Dimer and trimer of helium at ultralow energies”, Proceedings of the XV Conference of young scientists and specialists (14 – 19 February 2011, Dubna), JINR, Dubna, 2011, pp. 34–35.

3.3 Articles accepted for publication

1. E. A. Kolganova, V. Roudnev, and M. Cavagnero, “Helium trimer calculations with a public quantum three-body code”, *Physics of Atomic Nuclei* (accepted for publication).
2. V. S. Melezhik,“Multi-channel computations in low-dimensional few-body physics”, *Lecture Notes in Computer Science* (accepted for publication).
3. V. V. Pupyshev, “Modeling of the proton-proton reaction in the electron gas”, *Vestnik MSTU “Stankin”* (accepted for publication).
4. V. V. Pupyshev, “Proton-hydrogen atom scattering in effective two-body model”, *Physics of Atomic Nuclei* (accepted for publication).
5. V. V. Pupyshev, “Proton-hydrogen reaction in effective two-body model”, *Physics of Atomic Nuclei* (accepted for publication).
6. E. A. Solov’ev, “On the foundations of quantum physics”, *Physics Essays* (accepted for publication).

3.4 Preprints and data bases

1. S. Albeverio and A. K. Motovilov, “Sharpening the norm bound in the subspace peturbation theory”, *arXiv:1112.0149.*
2. V. B. Belyaev and M. B. Miller, “Quantum amplification on molecular-nuclear transitions”, *arXiv: 1104.2709.*
3. V. S. Melezhik,“Multi-channel computations in low-dimensional few-body physics”, *arXiv: 1110.3919*.
4. V. V. Pupyshev, “Proton-hydrogen atom scattering in an effective two-body model”, *JINR Preprint P4-2011-123, Dubna, JINR, 2011.*
5. V. V. Pupyshev, “Proton-hydrogen reaction in effective two-body model”, *JINR Preprint P4-2011-129, Dubna, JINR, 2011.*
6. S. N. Yang, S. S. Kamalov and L. Tiator, “P11 resonances with Dubna-Mainz-Taipei dynamical model for $\pi - N$ scattering and pion electromagnetic production”, *arXiv:1108.1673.*

3.5 Conference presentations

1. S. Albeverio and A. K. Motovilov, “The a priori Tan Θ Theorem in perturbation problem for spectral subspaces”, International Conference “Differential Equations and Related Topics” dedicated to I.G.Petrovskii (30 May – 4 June 2011, Moscow M. V. Lomonosov State University, Moscow, Russia), section talk.

2. P. Giannakeas, V. S. Melezhik, and P. Schmelcher,"d-wave confinement-induced resonances in harmonic waveguides", Verhandlungen der Deutschen Physikalischen Gesellschaft (13 – 18 March 2011, Dresden, Germany), poster.

3. S. S. Kamalov, "Pion photo- and electroproduction at threshold within the Dubna-Mainz-Taipei model", 28th Students Workshop Electromagnetic Interactions (4 – 9 September 2011, Bosen, Germany), invited talk.

4. E. A. Kolganova, "Helium trimer at ultra-low energies and Phillips line", XIV International Conference on Symmetry Methods in Physics (SYMPHYS-XV) (12 – 16 August 2011, Dubna), oral presentation.

5. A. A. Korobitsin and E. A. Kolganova, "Dimer and trimer of helium at ultralow energies", The XV Conference of young scientists and specialists (OMUS-2011) (14 – 19 February 2011, Laboratory of Information Technologies, JINR, Dubna), oral presentation

6. V. S. Melezhik "Multi-channel computations in low-dimensional few-body physics", International Conference "Mathematical Modeling and Computational Physics 2011" (4 – 8 July 2011, Stará Lesná, High Tatra Mountains, Slovakia), plenary lecture

7. V. S. Melezhik "Multichannel confinement-induced processes in harmonic waveguides", Workshop "Ultracold Few-Body Systems and Confinement-Induced Processes" (17 – 18 November 2011, Hamburg, Germany), invited talk

8. V. V. Pupyshev, "Modeling of low-energy collision of protons in electron gas", The Second International Scientific Symposium "The modeling of nonlinear processes and systems" (6 – 10 June 2011, Moscow State University of Technology STANKIN, Moscow, Russia), oral presentation.

9. I. I. Shlyk, "New meson-nuclei few-body systems", The XV Conference of young scientists and specialists (OMUS-2011) (14 – 19 February 2011, Laboratory of Information Technologies, JINR, Dubna), oral presentation.

10. E. A. Solov'ev, "On the foundations of quantum physics", The Seventh International Conference Quantum Theory and Symmetries (7 – 13 August 2011, Prague, Czech Republic), oral presentation.

3.6 Seminar talks

1. V. B. Belyaev, W. Sandhas, and I. I. Shlyk, "Few-body systems with φ mesons" (5 December 2011, Seminar on Nuclear Theory, Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna).

2. A. K. Motovilov, "The a priori TanΘ Theorem for spectral subspaces" (28 January 2011, Oberseminar Mathematik, Institut für Angewandte Mathematik, Universität Bonn, Bonn, Germany).

3. A. K. Motovilov, "The a priori TanΘ Theorem for spectral subspaces" (18 February 2011, Seminar of Laboratory of Operator Models and Spectral Analysis, Faculty of Mechanics and Mathematics, Moscow M. V. Lomonosov State University, Moscow).

4. V. V. Pupyshev, "Proton-hydrogen atom collision in effective two-body model" (15 November 2011, Seminar on Few-Body Systems, Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna).

5. E. A. Solov'ev, "On the foundations of quantum physics" (7 June 2011, Freie Universität, Berlin, Germany).

6. E. A. Solov'ev, "On the foundations of quantum physics" (14 June 2011, Max Born Institute, Berlin, Germany).

7. E. A. Solov'ev, "Rotational transitions of water molecules as a carrier of EEG signals in neuron network" (23 September 2011, Physical Faculty, St. Petersburg State University, St. Petersburg).

4 Visits

4.1 Conferences, schools

1. V. S. Melezhik, "Mathematical Modeling and Computational Physics 2011" (Stará Lesná, High Tatra Mountain, Slovakia), 04.07.2011–08.07.2011.

2. V. S. Melezhik, Workshop "Ultracold Few-Body Systems and Confinement-Induced Processes" (Hamburg, Germany), 17.11.2011–18.11.2011.

3. A. K. Motovilov, International Conference "Differential Equations and Related Topics" dedicated to I. G. Petrovskii (Moscow M. V. Lomonosov State University, Moscow, Russia), 30.05. 2011–02.06.2011.

4. V. V. Pupyshev, The Second International Scientific Symposium "The modeling of nonlinear processes and systems" (Moscow State University of Technology STANKIN, Moscow, Russia), 07.06.2011–8.06.2011.

5. E. A. Solov'ev, The Seventh International Conference Quantum Theory and Symmetries (Prague, Czech Republic), 07.08.2011–13.08.2011.

4.2 Collaboration visits

1. V. B. Belyaev, Physics Institute, Bonn University, Bonn, Germany, 14.12.2011–31.01.2012.

2. E. A. Kolganova, Physics Institute, Bonn University, Bonn, Germany, 02.04.2011–08.04.2011.

3. E. A. Kolganova, Physics Institute, Bonn University, Bonn, Germany, 10.05.2011–18.05.2011.

4. E. A. Kolganova, Physics Institute, Bonn University, Bonn, Germany, 29.11.2011 – 08.12.2011.

5. S. S. Kamalov, Institute of Nuclear Physics, Mainz University, Mainz, Germany, 03.04.2011–04.05.2011.

6. S. S. Kamalov, Institute of Nuclear Physics, Mainz University, Mainz, Germany, 23.08.2011–23.09.2011.

7. V. S. Melezhik, Center of Quantum Optics, Physics Department, University of Hamburg, Hamburg, Germany, 13.01.2011–23.02.2011.

8. V. S. Melezhik, Center of Quantum Optics, Physics Department, University of Hamburg, Hamburg, Germany,
20.08.2011–10.09.2011.

9. A. K. Motovilov, Institute for Applied Mathematics, Bonn University, Bonn, Germany,
13.01.2011–10.02.2011.

10. A. K. Motovilov, Physics Institute and Institute for Applied Mathematics, Bonn University, Bonn, Germany,
01.04.2011–13.05.2011.

11. A. K. Motovilov, Institute for Applied Mathematics, Bonn University, Bonn, Germany,
21.06.2011–19.07.2011.

12. A. K. Motovilov, Institute for Applied Mathematics, Bonn University, Bonn, Germany,
05.10.2011–03.12.2011.

13. E. A. Soloviev, Freie Universität, Berlin, Germany,
04.06.2011–14.06.2011.

14. I. I. Shlyk, Physics Institute, Bonn University, Bonn, Germany,
13.06.2011–23.06.2011.

15. I. I. Shlyk, Physics Institute of National Academy of Sciences, Minsk, Belarus
31.10.2011–30.11.2011.

5 Visitors

1. Claudio Cacciapuoti, Hausdorff Research Institute for Mathematics, University of Bonn, Bonn, Germany, 11.09.2011–18.09.2011.

2. Panagiotis Giannakeas, Center of Quantum Optics, Physics Department, University of Hamburg, Germany, 16.05.2011–27.05.2011

3. Nina Shevchenko, Institute of Nuclear Physics, Řež, Czech Republic,
20.10.2011–03.11.2011.

4. János Révai, Research Institute for Nuclear and Particle Physics, Budapest, Hungary,
16.05.2011–30.06.2011.

5. János Révai, Research Institute for Nuclear and Particle Physics, Budapest, Hungary,
15.09.2011–30.10.2011.

6. Werner Sandhas, Physics Institute, Bonn University, Bonn, Germany,
19.07.2011–30.07.2011.

6 Teaching

1. V. B. Belyaev: adviser of of A.Naumkin, Ph. D. student of Moscow State University, Moscow.

2. V. B. Belyaev: Professor of the Dubna University, lecture course “Nuclear Astrophysics”.

3. V. B. Belyaev: lecture course “Theory of few-body systems” at the Al-Farabi Kazakhstan National National University, Almaty, 6 – 17 November 2011.
4. E. A. Kolganova: Diploma adviser of A. Korobotsin, student of Dubna University, Dubna.
5. E. A. Kolganova: Diploma adviser of O. Klimenko, student of Dubna University, Dubna.
6. E. A. Kolganova: Diploma adviser of T. Alyab’eva, student of Dubna University, Dubna.
7. E. A. Kolganova: Diploma adviser of A. Nedelkin, student of Dubna University, Dubna.
8. E. A. Kolganova: Dozent of the Dubna University, lecture course “Mathematical modeling and numerical methods” (February–June and September–December, 2011).
9. V. S. Melezhik: Professor of the Dubna University, lecture course “General physics”(all the academic year), lecture course “History and methodology of physics” (September–December 2011), lecture course “Modern problems of quantum physics” (September–December 2011).
10. V. S. Melezhik: lecture course “Modern problems of ultracold atoms and molecules” for Ph.D students in Physics Department of Al-Farabi Kazakhstan National University, Almaty (22 November – 3 December 2011).
11. V. S. Melezhik: Ph. D. Thesis co-adviser of Panagiotis Giannakeas, Ph. D. student at Institute of Laser Physics, University of Hamburg, Hamburg, Germany.
12. V. S. Melezhik: Diploma (master thesis) adviser of O. Koval and E. Koval, students of Dubna University, Dubna.
13. A. K. Motovilov: Professor of the Dubna University, lectures and seminars on the course “Scattering theory for few-body systems” for 6th year students (September – December 2011).
14. V. V. Pupyshev: Diploma adviser of A. A. Shaposhnikov, student of Dubna University, Dubna.

7 Organizational activity

1. V. B. Belyaev: Member of the D. Sc. Panel of BLTP, JINR.
2. V. B. Belyaev: Member of the BLTP NTS.
3. E. A. Kolganova: Scientific Secretary of the Council for conferring of bachelor and magister degrees at the Theoretical Physics Department, Dubna University.
4. E. A. Kolganova: Scientific Secretary XV International Conference on Symmetry Methods in Physics (12 – 16 July 2011, Dubna, Russia, and 25 – 29 July 2011, Yerevan, Armenia).
5. E. A. Kolganova: Member of Organizing Committee, Advanced Studies Institute on Symmetries and Spin (2 – 9 May 2011, Prague, Czech Republic).
6. E. A. Kolganova: Scientific Secretary, Round Table Italy - Russia@Dubna on Black Holes in Mathematics and Physics (10 – 18 December 2011, Dubna, Russia).
7. E. A. Kolganova: Member of Organizing Committee, XIV International Workshop on High Energy Spin Physics (20 –24 September 2011, Dubna, Russia).

8. E. A. Kolganova: Member of Organizing Committee, IX Winter School on Theoretical Physics (30 January - 6 February 2011, Dubna, Russia).
9. E. A. Kolganova: Support of the BLTP Website.
10. V. S. Melezhik: Member of the D. Sc. Panel of LIT, JINR.
11. V. S. Melezhik: Member of the Program Committee of the International Conference “Mathematical Modeling and Computational Physics 2011” (4 – 8 July 2011, High Tatra Mountains, Slovakia).
12. V. S. Melezhik: Member of the BLTP Expert commission.
13. A. K. Motovilov: Member of Editorial Board of the “Few-Body Systems” journal.
14. A. K. Motovilov: Member of the BLTP NTS.
15. V. V. Pupyshev: Secretary of the BLTP Commission for Ph.D. (C.Sc) examinations.