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

1997 Annual Activity Report

CONTENTS

I. MAIN RESULTS

A universal behavior of the resonance trajectories for three-particle systems under Efimov conditions was discovered in a multichannel model generated by the hyperspherical adiabatic expansion.

An operator interpretation for resonances generated by a class of 2×2 matrix Hamiltonians was found. Completeness and even basis properties for the resonance root vectors (including the resonance eigenvectors) in a subspace have been proved.

Influence of a pre-threshold nuclear resonance on a molecular level was studied and the inverse–proportional dependence of the molecular width on the nuclear one was proved.

A mathematically rigorous method has been worked out for solving three–body bound state and scattering problems where the inter-particle interaction is of a hard-core nature. The method has been employed to obtain the ground– and Efimov–type excited–state energies for the Helium trimer and to calculate, for the first time, the scattering phase shifts and wave–functions for the He atom – He dimer at ultra–low energies.

It was established that the regular and irregular scattering wave functions for a superposition of the repulsive Coulomb and central rapidly decreasing potentials can be represented as infinite series, the distance and momentum being separated in the summands. Also it was shown that the three-particle Raynal–Revai coefficients can be found via solving a simple set of linear coupled equations or by calculating one-dimensional integrals.

In framework of a semiclassical approach the charge–exchange processes of the type $\mu h + Z \to Z\mu + h$, with $h = p,\ d$ and $Z = 1, 2, 3$ have been studied. The role of triple collisions in the electromagnetic destruction of some light nuclei at the center of sun conditions was clarified. New type of muonic molecules built via collision of slow muons and D_3^+ ion was predicted.

Binding energies, radiative and nonradiative decay rates and γ-ray spectra of the charge–nonsymmetric muonic molecular ions $^{3,4}Hed\mu$ for the states of the total angular momentum $L = 0,\ 1,\ 2$ have been calculated. A comparison of the calculated γ-ray spectra with recent experiments confirms the assumption on the $\mathrm{HeH}\mu$ decay from the $L = 1$ state.

Rate of the Auger transition for a number of states of the $^3\mathrm{He}\bar{\mathrm{p}}\mathrm{e}$, $^4\mathrm{He}\bar{\mathrm{p}}\mathrm{e}$ and $^6\mathrm{He}\bar{\mathrm{p}}\mathrm{e}$ systems have been calculated and the substantial isotopic effect was found. Also an explanation of the isotopic effect in the generation of multicharged ions in the electron-cyclotron resonance ion source was found.

An efficient method for production of exotic systems containing positron e^+ and antiproton $\bar{\mathrm{p}}$ in the charge–exchange reactions was proposed.

A new operator for pion photo- and electroproduction has been developed for the application to the reactions on nuclei at equivalent photon energies up to 1 GeV. Within the model a good agreement with experimental data for pion photo- and electroproduction on nucleon has been obtained. Predictions were given for future experiments on pion electroproduction to be done at Mainz, Bonn and TJNAF.

A role of the first radial excitation of the pion, ($\pi'(0^-)$) in the OBE exchange contribution in lepton deep-inelastic scattering (DIS) has been studied. The π'-meson exchange contribution is calculated in addition to the known pionic contribution. The interference effects are found to be negligible for the nucleon quark distributions and to modify only higher moments of the quark distributions.

New elastic scattering data on $\pi^+ + {}^{12}C$ scattering in the energy range of 18 – 44 MeV have been analysed within the framework of the unitary pion–nucleus theory. It was shown that these data provide us with information on the pion-nucleus D-wave interaction at low energies.

The baryonic decays of hypernuclear resonances of $1p$-shell hypernuclei built on $s_\Lambda p^{-1}$, $p_\Lambda p^{-1}$, and $s_\Lambda s^{-1}$ 1 particle – 1 hole configurations are analyzed within the framework of the translationally invariant shell model and selection rules in the quantum numbers $[f]$ and (λ, μ) are applied. These structure selection rules give a natural interpretation of the features observed in the decay of high excited states of the primary hypernuclei.

Reflectionless multichannel interaction matrix without bound states was shown to be a fundamental elementary constituent of quantum transformations, similarly to the one-channel soliton–like potentials, while a creation of “nonphysical” states was found to give a possibility to change infinite partial spectral weight factors within exactly solvable models. Also, it was demonstrated, employing a qualitative algorithm, how the pole positions of the multichannel scattering matrix in the upper complex k-plane manage the form of interaction as well as a role of antiresonances was clarified.

II. LIST OF PUBLICATIONS

A. MONOGRAPHS

B.N.Zakhariev, "New ABC of Quantum Mechanics", to be published by Udmurtia University (Izhevsk)

B. JOURNAL PUBLICATIONS

1. V.B.Belyaev, O.I.Kartavtsev, V.I.Kochkin, and E.A.Kolganova, "Decay rates and γ-ray spectra of $\mathrm{HeH}\mu$ systems", *Zeit. Physik D* **41**, *239–244 (1997).*

2. V.M. Bystritsky, V.M. Grebenyuk, S.S. Parzhitski, F.M. Penkov, V.T. Sidorov, V.A. Stolupin, T.L. Bulgakov, G.A. Mesyats, A.A. Sinebryukhov, V.A. Sinebryukhov, S.A. Chaikovsky, A.V. Luchinsky, N.A. Ratakhin, S.A. Sorokin, Vit.M. Bystritsii, A. Toor, M. Filippowicz, A. Gula, E. Laki, J. Wozniak, and E. Gula, "A new approach in the experimental studies of nuclear reaction at ultralow energy", *Nucleonica* **42** *No. 4, 775–794 (1997).*

3. S.A.Rakityansky, S.A.Sofianos, L.L.Howell, M.Braun, and V.B.Belyaev: "Nonradiative proton-deuteron fusion in stellar plasma" *Nucl.Phys.A* **613**, *132-146 (1997).*

4. V.B.Belyaev, and A.K.Motovilov, "Perturbation of embedded eigenvalue by a nearly resonance", *Teor. Mat. Fiz.* **111**, *77–93 (1997) (Russian)*

5. B.N.Zakhariev, and V.M.Chabanov, "New situation in quantum mechanics (wonderful potentials from the inverse problem)", *Inverse Problems* **13**, *R1–R33 (1997).*

6. V.M.Chabanov, B.N.Zakhariev, and S.A.Sofianos, "Universal elementary constituents of potential transformations shifting waves (qualitative theory)", *Ann.Phys.* **6**, *136–143 (1997).*

7. B.N.Zakhariev, and L.G.Zastavenko, "Tunneling between two different wells", *J. Mosc.Phys. Soc.***7**, *85-90 (1997).*

8. S.S. Kamalov, J.A. Oller, E. Oset, and M.J. Vicente-Vacas, "Meson exchange currents in kaon scattering on the lightest nuclei", *Phys. Rev. C* **55**, *2985–2990 (1997)*

9. O.I.Kartavtsev, S.I.Fedotov, and D.E.Monakhov, "Isotopic effect in the decay of antiprotonic helium atoms", *Hyperfine Interactions* **109**, *125–131 (1997).*

10. O.I.Kartavtsev and I.N.Meshkov, "Method of the in–flight production of exotic systems in the charge–exchange reactions", *Nucl. Instr. Meth. A* **391**, *221–223 (1997).*

11. L.Majling, V.N.Fetisov, and R.A.Eramzhyan, "Decay properties of $1p$-shell hypernuclei: II. Baryon decays", *Elem. Part. Nucl.* **28** *101–133 (1997).*

12. A.K.Motovilov, Representations for the three–body T–matrix, scattering matrices and resolvent in unphysical energy sheets, *Math. Nachr.* **187**, *147–210 (1997).*

13. A.K.Motovilov, S.A.Sofianos, and E.A.Kolganova, Bound states and scattering processes in the $^4He_3$ atomic system, *Chem. Phys. Lett.* **275**, *168–172 (1997).*

14. E.A.Kolganova, A.K.Motovilov, and S.A.Sofianos, Ultralow energy scattering of a He atom off a He dimer, *Phys. Rev. A* **56**, *1686–1689 (1997).*

15. E.A.Kolganova, and A.K.Motovilov, Using Faddeev differential equations to calculate three-body resonances, *Phys. Atom. Nucl.* **60**, *177–185 (1997).*

16. F.M.Pen'kov, "Nuclear transition from molecular resonances", *Phys. Atom. Nucl.* **60**, *897–904 (1997)*

17. F.M.Pen'kov "Mechanisms for long-range forces in the 'three atoms + electron' system", *JETP* **84**, *678–681 (1997)*

18. M.Kh.Khankhasayev, A.Szcshurek, and J.Speth, "On mesonic interference phenomena in deep inelastic scattering", *Z. Phys.* **A 359**, *191 (1997)*

C. ARTICLES ACCEPTED FOR PUBLICATIONS

1. B.N.Zakhariev and M.A.Mineev, "Separation of a chosen state from almost degenerated multiplet as an instructive space–localization control", *J. Mosc.Phys. Soc.* **7**, *N3 (1997).*

2. B.N.Zakhariev, "Spectrum of the Schrödinger operator", *Physical Enciclopediae,* **5**, *(1998).*

3. S.S. Kamalov, and E. Oset, "Coherent two pion photoproduction on ^{12}C" *Nucl. Phys. A, 1997*

4. K.I. Blomqvist, W.U. Boeglin, R. Böhm, M. Distler, R. Edelhoff, J. Friedrich, R. Geiges, M. Kahrau, S.S. Kamalov, M. Kirchbach, M. Korn, H. Kramer, K.W. Krygier, V. Kunde, M. Kuss, J.M. Laget, A. Liesenfeld, K. Merle, R. Neuhausen, E.A.J.M. Offermann, Th. Pospischil, M. Potokar, C. Rangacharyulu, A. Richter, A.W. Richter, A. Rokavec, G. Rosner, P. Sauer, St. Schardt, G. Schrieder, T. Suda, L. Tiator, B. Vodenik, A. Wagner, Th. Walcher, and St. Wolf, "Pion electroproduction in the $^3He(e,e'\pi^+)^3H$ reaction" *Nucl. Phys. A, 1997*

5. L.Majling, and R.A.Eramzhyan, "Baryonic decays of the excited states of the $1p$-shell Λ-hypernuclei," *Izvestia VUZov (in Russian)*

6. R.Mennicken, and A.K.Motovilov, Operator interpretation of resonances arising in spectral problems for $\mathbf{2} \times \mathbf{2}$ operator matrices, To appear in *Math. Nachr.*

7. E.A.Kolganova, A.K.Motovilov, and S.A.Sofianos, Three-body configuration space calculations with hard-core potentials, To appear in *J. Phys. B.*

8. V.V.Pupyshev, "Low-energy expansions in nuclear physics", *Elem. Part. and Atom. Nucl. (1998)*

9. M.Kh.Khankhasayev, V.Yu.Alexakhin, S.I.Gogolev, Zh.B.Kurmanov, K.O.Oganesyan, E.A.Pasyuk, C.Morris, J.M.O'Donnel, M.N.Rawool–Sullivan, M.K.Jones, F.F.Guber, and A.I.Reshetin, "$\pi^+ + {}^{12}$C elastic scattering between 18 and 44 MeV", *Phys. Rev C (1998).*

D. PREPRINTS AND DATA BASES

1. V.B.Belyaev, D.E.Monakhov, S.A.Sofianos, and W.Sandhas, "Existence and transitions properties of three-deuteron muonic molecule ($d_3e_2^-\mu^-$)", *LANL E-Print nucl-th/9711056*.

2. V.B.Belyaev, D.E.Monakhov, N.Shevchenko, S.A.Sofianos, S.A.Rakityansky, M.Braun, L.L.Howell, and W.Sandhas, "Nuclear fusion via triple collisions in solar plasma", *LANL E-print nucl-th/9709018*.

3. V.M.Bystritsky and F.M. Pen'kov, "On experimental determination of characteristics of nuclear fusion reactions from μ-molecular resonance states", *Preprint JINR E15-97-329, JINR, Dubna, 1997*, submitted to *Yadernaya Fizika*.

4. S.S.Kamalov, and E.Oset, "Coherent two pion photoproduction on ^{12}C", *LANL E-print nucl-th/9704024*.

5. S.S.Kamalov, J.A.Oller, E.Oset, and M.J.Vicente-Vacas, "Meson exchange currents in Kaon scattering on the lightest nuclei", *LANL E-print nucl-th/9702030*.

6. O.I.Kartavtsev, and G.D.Shirkov, "Role of charge-exchange processes in the plasma of ECR ion sources", *Preprint RIKEN, Tokyo, 1997*

7. E.A.Kolganova, and A.K.Motovilov, "Three-body resonances in framework of the Faddeev configuration space approach", *LANL E-print nucl-th/9702037*.

8. R.Mennicken, and A.K.Motovilov, "Operator interpretation of resonances arising in spectral problems for $\mathbf{2}\times\mathbf{2}$ operator matrices", *LANL E-print funct-an/9708001, 58 pp.*

9. A.K.Motovilov, S.A.Sofianos, and E.A.Kolganova, "Bound states and scattering processes in the ^{4}He$_3$ atomic system", *LANL E-print physics/9709037*.

10. V.M.Bystritsky, and F.M.Pen'kov, "On experimental determination of characteristics of nuclear fusion reactions from mu-molecular resonance states", *Preprint JINR, E15-97-329, Dubna, 1997*, Submitted to Phys. Atom. Nucl.

11. V.V.Pupyshev, "Low-energy expansions for the one-dimensional Shrödinger scattering problem", *Preprint JINR, E4-97-125, Dubna, 1997*

E. CONFERENCE CONTRIBUTIONS

1. V.B.Belyaev, O.I.Kartavtsev, V.I.Kochkin, and E.A.Kolganova, Calculation of decay rates of the HeHμ systems, *Proc. of 9th Intern. Conf. on Computational Modelling and Computing in Physics, CMCP'96 (Dubna, September 16–21, 1996). JINR, Dubna, 1997. — P. 105-109.*

2. V.B.Belyaev, D.E.Monakhov, N.Shevchenko S.A.Sofianos, S.A.Rakityansky, M.Braun, L.L.Howell, and W.Sandhas, "Nuclear Fusion via Triple Collisions in Solar Plasma", To appear in *Proc. of XV Intern. Conf. on Few-Body Problems in Physics, Groningen, The Netherlands 22–26 July 1997*.

3. L.Majling, and R.Eramzhyan, "Baryonic decays of the excited states of the $1p$-shell Λ-hypernuclei" , to appear in *Proc. of Intern. Conference on Nuclear Structure and Related Topics Dubna, September 1997.*

4. L.Majling, "Baryonic decays of p-shell hypernuclei", to appear in *Proc. of Intern. Conference on Hypernuclear and Strange Particle Physics (HYP97), BNL (USA), October 1997* which will be published in *Nucl Phys. A* (April 1998), 10 pp.

5. E.A.Kolganova, and A.K.Motovilov, Three-body resonances in framework of the Faddeev configuration space approach, *Proc. of 9th Intern. Conf. on Computational Modelling and Computing in Physics, CMCP'96 (Dubna, September 16–21, 1996). JINR, Dubna, 1997. — P. 177-180.*

6. R.Mennicken, and A.K.Motovilov, "Operator interpretation of resonances generated by some operator matrices", to appear in *Proc. of Mark Krein International Conference "Operator Theory and Applications", Odessa, Ukraine, 18.08–22.08.1997.*

7. F.M.Pen'kov, "Three–atomic clusters", to appear in *Proc. of 8th International Conference on Symmetry Methods in Physics, Dubna, 1997* (to be published in *Phys. Atom. Nucl. (1998)*).

8. V.V. Pupyshev, "Some properties of the Raynal–Revai coefficients", to appear in *Proc. of 8th International Conference on Symmetry Methods in Physics, Dubna, 1997* (to be published in *Phys. Atom. Nucl. (1998)*).

9. M.Kh. Khankhasayev, and H.S. Plendl, "An overview of the NMTW'96 Dubna Workshop" (Plenary talk), *In Proc. of the 2nd Intern. Conf. on Accelerator-Driven Transmutation Technologies and Applications, June 3–7, 1996, Kalmar, Sweden, Ed. Henri Conde, Published by Uppsala University, Stockholm, 1997.*

10. V.M.Chabanov, and B.N.Zakhariev, "Qualitative physics in spectral, scattering and decay control", *Lecture Notes in Physics "Inverse and Algebraic Quantum Scattering Theory" pp. 30–44 (1997).*

11. V.M.Chabanov, B.N.Zakhariev, S.A.Sofianos, and M.Braun "Potential reversal and reflectionless impurities in periodic structures" *Lecture Notes in Physics "Inverse and Algebraic Quantum Scattering Theory", pp. 197–203 (1997).*

III. VISITS

A. CONFERENCES, SCHOOLS

1. V.B.Belyaev, XV International Conference on Few-Body physics, Groningen, The Netherlands, 28.07–04.08.1997

2. S.S. Kamalov, 14th International Workshop on Electromagnetic Interactions, Bosen, Germany, 6.09–11.09.1997

3. L.Majling, International Conference on Hypernuclear and Strange Particle Physics (HYP97), Brookhaven National Laboratory, Upton, USA, 13.10.–18.10.1997

4. A.K.Motovilov, XV International Conference on Few-Body physics, Groningen, The Netherlands, 28.07–04.08.1997

5. A.K.Motovilov, Mark Krein International Conference “Operator Theory and Applications”, Odessa, Ukraine, 18.08–22.08.1997

6. F.M.Pen’kov, Workshop “Few-Body Problems in Nuclear Physics and Related Fields”, European Centre for Theoretical Studies in Nuclear Physics and Related Areas, Trento, Italy, 8.09– 27.09.1997.

7. B.N.Zakhariev, XII International Congress of Mathematical Physics, 13.07–19.07.1997, Brisbane, Australia.

8. B.N.Zakhariev, Eight Lectures at Soros Conference, Ivanovo, 10.01.97; Saransk, 24.02.1997; Apatity, 6.05-7.05.1997.

9. B.N.Zakhariev, Inter-High-School Conference, Izhevsk 21.04–22.04.1997.

B. COLLABORATION VISITS

1. V.B.Belyaev, Bonn University, Germany, June–August 1997
2. V.B.Belyaev, Central Institute of Physics, Budapest, Hungary, July 1997.
3. V.B.Belyaev, RCNP, Osaka University, Japan, 11.1997–09.1998.
4. S.S.Kamalov, University of Mainz, Germany, 04.1997; 08.1997–08.1998.
5. O.I.Kartavtsev, Institute of Nuclear Particle and Nuclear Science, Budapest, Hungary, 31.07–12.08.1997
6. A.K.Motovilov, University of Regensburg, Germany, 5.05–5.08.97.
7. M.Kh.Khankhasayev, Florida State University, Tallahassee, Florida, USA, 01.01–31.05.1997; 8.08–31.12.1997.

IV. VISITORS

1. J.Revai, Central Institute of Physics, Budapest, Hungary, April 1997
2. L.Tiator, Institute of Nuclear Physics, University of Mainz, Germany, 01.07-14.07.1997

V. GRANTS

1. RFBR 96-02-18678, 01.96–12.97. Head: V. B. Belyaev. Participants from JINR: A. K. Motovilov, E. A. Kolganova (LCTA), and S. A. Rakityansky (LNP).

2. RFBR 96-02-18289, 01.1996–12.1997. Head: O. I. Kartavtsev. Participants: S. I. Fedotov and D. E. Monakhov.

3. RFBR 96-01-01716, 01.96–12.98. Head: A. K. Motovilov, no other participants of JINR.

4. RFBR 96-01-01292, 01.96–12.98. Head: A. A. Shkalikov, Faculty of Mathematics and Mechanics, Moscow State University. Participants from JINR: A. K. Motovilov.

5. RFBR 96-02-17021, 01.96–12.97. Head: S. L. Yakovlev, Department of Computational Physics, St. Petersburg State University. Participants from JINR: A. K. Motovilov and E. A. Kolganova (LCTA).

6. RFBR 96-02-17383, 01.96–12.97. Head: B.N.Zakhariev. Participants: V.M.Chabanov.

7. RFBR 97–02–27081, 13.07–19.07.1997. B.N.Zakhariev, travel grant for participation in XII International Congress of Mathematical Physics, Brisbane, Australia.

8. Heisenberg–Landau Program, 11.1996–11.1997. V.B.Belyaev.

9. Heisenberg–Landau Program, 11.1996–11.1997. S.S.Kamalov.

10. NATO Award for Advanced Study Institute “Chemical Separation Technologies and Related Methods of Nuclear Waste Management: Applications, Problems and Research Needs”, 1998, Dubna, Russia; ENVIR.ASI 961307,$84,100. Co-Directors: M.Kh.Khankhasayev and G. R. Choppin (FSU, Tallahassee, Florida, USA)

11. INTAS 93–0337–EXT “Few–Body physics network”, 01.01.1996–31.12.1997. Coordinator: W.Pleassas (University of Graz, Austria). Contractor from JINR: V.B.Belyaev.

12. INTAS 93–0249–EXT “Hilbert and Krein space operators: extension problems and functional models”. 01.07.1996–31.12.1997. Coordinator: M.A.Kaashoek (Vrije Universiteit Amsterdam, The Netherlands). Supported person in JINR: A.K.Motovilov.

13. DFG 436 RUS 17/105/96, 05.05–05.08.97. A.K.Motovilov, grant for research visit to Department of Mathematics, Regensburg University, Germany.

14. Soros professorship: B.N.Zakhariev (1997)

VI. TEACHING

- V.B.Belyaev: Supervision of the C. Sc. thesis preparation by D.E.Monakhov, post-graduate student of Moscow Physics Engineering Institute. Tentative title of the thesis: “Exotic three particles systems and processes”.

- V.B.Belyaev and A.K.Motovilov: Supervision of the C. Sc. thesis defended on 15.10.1997 by E.A.Kolganova, Researcher of LCTA, JINR. Title of the thesis: “Resonance and bound states in three–body systems”.

- A.K.Motovilov: Supervision of diploma research work by student of Tver State University D.V.Belyakov. Title of the work: “Scattering and resonances in multichannel problems with binary channels”.

- F.M.Penkov: Supervision of diploma research work by student of Irkutsk State University D.V.Naumov. Title of the work: “Coulomb barrier in real molecular systems”.

- B.N.Zakhariev: Lectures “Lessons on quantum intuition” at Moscow Institute of Physics and Technology, University Center of JINR, Saransk State University, Saransk Pedagogical Institute, Moscow Physics and Engineering Institute; RAS Institute of General Physics, Phys.–Math. Schools of Apatity and Izhevsk.

- B.N.Zakhariev: Supervision of the C. Sc. thesis preparation by V.M.Chabanov, Researcher of BLTP. Title of the thesis: “Qualitative theory of quantum systems transformations in the inverse problem approach”

VII. ORGANIZATIONAL ACTIVITY

- V.B. Belyaev, Member of the BLTP NTS
- L. Majling, Member of the BLTP NTS
- B.N. Zakhariev, Member of the BLTP NTS
- B.N. Zakhariev: Member of the Dr. Sc. panel in BLTP, JINR
- V.B. Belyaev, Member of advisory board of European Few-body Conference, Grenoble, France (1998)
- V.B. Belyaev, Member of advisory board of International Conference “Mesons and light nuclei”, Rzez, Chech Republic (1998)
- V.B. Belyaev, Member of editorial board of the journal “Few–Body Systems”
- M.Kh. Khankhasayev, Co-Director of the NATO Advanced Study Institute “Chemical Separation Technologies and Related Methods of Nuclear Waste Management: Applications, Problems and Research Needs”
- B.N. Zakhariev, hairman of Organizational Committee of the School–Seminar “Secrets of Quantum and Mathematical Intuition”, Dubna, JINR, 17.06–20.06.1997.
- V.M. Chabanov, Vice-Chairman of Organizational Committee of the School–Seminar “Secrets of Quantum and Mathematical Intuition”, Dubna, JINR, 17.06–20.06.1997.