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

## 2001 Annual Activity Report

# 1 Staff of the BLTP Sector 11 in 2001

1. V.B. Belyaev (Prof., Dr. Sc., Principal Researcher)
2. S.S. Kamalov (Dr., Senior Researcher)
3. M.Kh. Khankhasaev (Dr. Sc., Leading Researcher)
4. A.V. Matveenko (Dr. Sc., Leading Researcher)
5. D.E. Monakhov (Dr., Researcher)
6. A.K. Motovilov (Dr., Head of the Group)
7. F.M. Pen'kov (Dr., Senior Researcher)
8. V.V. Pupyshev (Dr., Senior Researcher)
9. N.V. Shevchenko (M. Sc., Junior Researcher)
    - M.V. Agaverdyev (M. Sc., Ph. D. Student)

## 2 Main results

A soluble model of weakly coupled "molecular" and "nuclear" Hamiltonians has been studied in order to exhibit explicitly the mechanism leading to the enhancement of fusion probability in case of a narrow near-threshold nuclear resonance. Further, the lattice structures arranged of molecular cells of this type were considered. It was shown that if the real part of the narrow nuclear resonance lies within the molecular band generated by the intercellular interaction, an enhancement, proportional to the inverse width of the nuclear resonance, is to be expected. [A.K. Motovilov, W. Sandhas, and V.B. Belyaev, J. Math. Phys. **42** (2001), 2490]

The hyperharmonics method has been applied to the three-body Schrödinger and Faddeev equations with inverse square two-body interactions. Exact solutions of those equations were constructed as products of a hyperradial Bessel function and finite linear combination of the hyperharmonics. For these solutions the existence criterion has been found and analyzed. [V.V. Pupyshev, Theor. Math. Phys. **128** (2001), 1061]

It was shown that accurate analytic diagonalization of the Coriolis coupling terms within the hyperradial-adiabatic approach results in the $J(J+4)/(2MR^2)$ centrifugal potential [A.V. Matveenko, J. Phys. **B 34**(2001), L87]. Making use of a new kinematical description of a free three-body problem in hyperspherical coordinates, a two infinite series of matrix identities interconnecting triangle angles, particle masses and internal hyperspherical angles have been derived. The corresponding relations for the matrix elements are practically all new. [A.V. Matveenko and J. Czerwonko, J. Phys. **A 34** (2001), 9057]

The spin structure of the nucleon resonance region has been analyzed on the basis of the MAID phenomenological model. Predictions were given for the Gerasimov-Drell-Hearn sum rule as well as generalized integrals over spin structure functions. The dependence of these integrals on momentum transfer were studied and rigorous relationships between various definitions of generalized Gerasimov-Drell-Hearn integrals and spin polarizabilities were derived. [D. Drechsel, S.S. Kamalov, and L. Tiator, Phys. Rev. **D 63** (2001), 114010]

It was shown that, within a meson-exchange dynamical model describing most of the existing pion electromagnetic production data up to the second resonance region, one is also able to obtain a good agreement with the $\pi^0$ photo- and electroproduction data near threshold. The only sizable discrepancy between our results and the data is in the P-wave amplitude $P_3 = 2M_{1+} + M_{1-}$, where our prediction underestimate the data by about 20%. In the case of $\pi^0$ production, the effects of final state interaction in the threshold region are nearly saturated by single charge exchange rescattering. This indicates that in ChPT it might be sufficient to carry out the calculation just up to one-loop diagrams for threshold neutral pion production. [S.S. Kamalov, G.Y. Chen, S.N. Yang, D. Drechsel, and L. Tiator, Phys. Lett. **B522** (2001), 27]

Photoproduction of $\eta$-mesons off deuteron was studied within the Alt-Grassberger-Sandhas formalism for different parameters of $\eta N$ interaction. The calculations revealed peaks in the energy dependence of the total cross-section. [N.V. Shevchenko, V.B. Belyaev, S.A. Rakityansky, S.A. Sofianos, and W. Sandhas, Nucl. Phys. **A 689** (2001), 383]

Investigations of $\eta$-few-nucleon systems dynamics in the different process at low energies was performed. The $\eta$-deuteron system was treated on the basis of the exact few-body Alt-Grassberger-Sandhas equations. Investigations of the $\eta - {}^3$H, $\eta - {}^3$He, and $\eta - {}^4$He systems were performed within the framework of a finite-rank approximation of the nuclear Hamiltonian. [V.B.Belyaev,

N.V.Shevchenko, S.A.Rakityansky, S.A.Sofianos, and W.Sandhas, Few Body Syst. Suppl. **13** (2001), 262]

The experimental results of measurements of the astrophysical S-factor for $dd$-reaction at very low deuteron collision energies using liner plasma technique were presented. The experiment was fulfilled at the high current generator of the High-Current Electronics Institute, Tomsk, Russia. [V. Bystritskii,..., F.M. Pen'kov,... *et al.*, Kerntechnik **66** No. 1–2 (2001), 42]

The $^4He_3$ system was investigated using a hard-core version of the Faddeev differential equations. Realistic $^4$He–$^4$He interactions were employed, among them the LM2M2 potential by Aziz and Slaman and the recent TTY potential by Tang, Toennies and Yiu. The binding energies of the $^4$He trimer were calculated, but the paper concentrates in particular on scattering observables. The scattering lengths and the atom-diatom phase shifts were calculated for center of mass energies up to 2.45 mK. It is found that the LM2M2 and TTY potentials, although of quite different structure, give practically the same bound-state and scattering results. [A.K. Motovilov, W. Sandhas, S.A. Sofianos, and E.A. Kolganova, European Phys. J. **D 13** (2001), 33]

# 3 List of publications

## 3.1 Books

1. Eds. G. Choppin, M. Khankhasayev, and Hans Plendl, "Chemical Separations in Nuclear Waste Management: The State of Art and a Look to the Future", *Bettelle Press, Richmond, USA, 2001, pp. 96.*

## 3.2 Journal publications

1. V.B. Belyaev, A.K. Motovilov, M.B. Miller, A.V. Sermyagin, I.V. Kuznetzov, Yu.G. Sobolev, A.A. Smolnikov, A.A. Klimenko, S.B. Osetrov, and S.I. Vasiliev, "Search for nuclear reactions in water molecules", *Physics Letters* **B522**, *222–226 (2001).*

2. V.B. Belyaev, N.V. Shevchenko, S.A. Rakityansky, S.A. Sofianos, and W. Sandhas, "Microscopic description of $\eta$-nuclear systems", *Few Body Syst. Suppl.* **13**, *262–273 (2001).*

3. V. Bystritskii..., F.M. Pen'kov et al., "The Astrophysical S-factor for the $dd$-reaction at keV-energy range", *Kerntechnik* **66**, *42–46 (2001).*

4. V. Bystritskii..., F.M. Pen'kov et al. "The Astrophysical S-factor for the $dd$-reaction at ultralow energies", *Yadernaya Fizika* **64**, *920–925 (2001).*

5. D. Drechsel, S.S. Kamalov and L. Tiator, "The GDH sum rule and related integrals," *Phys. Rev. D* **63**, *114010–114035 (2001).*

6. S.S. Kamalov, G.Y. Chen, S.N. Yang, D. Drechsel and L. Tiator, "$\pi^0$ photo- and electroproduction at threshold within a dynamical model," *Phys. Lett. B* **522**, *27–36 (2001).*

7. S.S. Kamalov, D. Drechsel, O. Hanstein, L. Tiator and S. N. Yang, "Unitary Isobar (Maid) and Dynamical Models for Pion Electroproduction," *Nucl. Phys. A* **684**, *321–323 (2001).*

8. S.S. Kamalov, E. Oset and A. Ramos, "Chiral unitary approach to the K- deuteron scattering length," *Nucl. Phys. A* **690**, *494–508 (2001).*

9. S.S. Kamalov, S.N. Yang, D. Drechsel, O. Hanstein and L. Tiator, "$\gamma * N \to \Delta$ transition form factors: A new analysis of the JLab data on $p(e,e'p)\pi^0$ at $Q^2 = 2.8$ (GeV/c)$^2$ and 4.0 (GeV/c)$^2$," *Phys. Rev. C* **64**, *032201–032207 (2001).*

10. E.A. Kolganova, A.K. Motovilov, and Y.K. Ho, "Complex scaling of the Faddeev operator", *Nucl. Phys.* **A684** *(1-4), 623–625 (2001).*

11. L.M. Lekala, A.S. Rakityansky and D.E. Monakhov "Triple $e^-pn$ collisions and primordila formation of deutron", *South African Journal of Science* **C 97**, *(2001).*

12. A.V. Matveenko, "Canonical three-body angular basis", *Few-Body Systems* **30**, *259–267 (2001).*

13. A.V. Matveenko, "Comment on "Full Ambiguity-Free Quantum Treatment ..." by A. Igarashi and C.D. Lin", *Phys. Rev. Lett.* **86** , *746 (2001).*

14. A.V. Matveenko, "Diagonalization of the Coriolis couplings", *J. Phys.* **B34**, *L87–L92 (2001).*

15. A.V. Matveenko, "Excited muonic atom scattering: new adiabatic approach", *Hyperfine Int.* **138**, *117–120 (2001).*

16. A.V. Matveenko and E.O. Alt, "Does He-trimer have bound rotational states ?", *Hyperfine Int.* **138**, *421–425 (2001).*

17. A.V. Matveenko, E.O. Alt and H. Fukuda, "Rotational three-body resonances: a new adiabatic approach", *Few-Body Systems Suppl.* **13**, *140–151 (2001).*

18. A.V. Matveenko and J. Czerwonko, "Hyper-trigonometry of the particle triangle", *J. Phys.* **A34** , *9057–9064 (2001).*

19. A.K. Motovilov, "The structure of the T and S matrix on the unphysical energy sheets for the problem of three quantum particles", *Physics of Particles and Nuclei* **32** *Suppl. 1, 76–79 (2001).*

20. A.K. Motovilov, W. Sandhas, and V.B. Belyaev, "Perturbation of a lattice spectral band by a nearby resonance", *J. Math. Phys.* **42**, *2490-2506 (2001).*

21. A.K. Motovilov, W. Sandhas, S.A. Sofianos, and E.A. Kolganova, "Binding energies and scattering observables in the $^4He_3$ atomic system", *European Phys. J.* **D13**, *33–41 (2001).*

22. A.K. Motovilov, W. Sandhas, S.A. Sofianos, and E.A. Kolganova, "Binding energies and scattering observables in the $^4He_3$ atomic system", *Nucl. Phys.* **A684** *(1-4), 646–648 (2001).*

23. T. Pospischil..., S. S. Kamalov *et al.* [A1 Collaboration], "Measurement of the recoil polarization in the $p(e,e'p)\pi^0$ reaction at the Delta(1232) resonance," *Phys. Rev. Lett.* **86**, *2959–2962 (2001).*

24. V.V. Pupyshev “Three-particle problem with pairwise interactions inverse proportional to squared distance”, *Theor. Math. Phys.* **128**, *1061–1077 (2001).*

25. S.A. Rakityansky, S.A. Sofianos, N.V. Shevchenko, V.B. Belyaev, and W. Sandhas, “Near–threshold $\eta$d resonance”, *Nucl. Phys* **A684**, *383–385 (2001).*

26. A. Ramos..., S.S. Kamalov *et al.*, “Antikaons in nuclei and dense nuclear matter,” *Nucl. Phys. A* **691**, *258–267 (2001).*

27. N.V. Shevchenko, V.B. Belyaev, S.A. Rakityansky, S.A. Sofianos, and W. Sandhas, “Photoproduction of $\eta$-mesons off light nuclei”, *Nucl.Phys.* **A 689**, *383–386 (2001).*

28. L. Tiator, D. Drechsel, O. Hanstein, S.S. Kamalov and S. N. Yang, “The E2/M1 and C2/M1 ratios and form-factors in $N \to \Delta$ transitions,” *Nucl. Phys. A* **689**, *205–214 (2001).*

### 3.3 Articles accepted for publication

1. V. Hardt, R. Mennicken, and A.K. Motovilov, “Factorization theorem for the transfer function associated with a $2 \times 2$ operator matrix having unbounded couplings”, Journal of Operator Theory.

2. V.V. Pupyshev “Some expansions in the three-body problem”, Physics of Particles and Nuclei.

### 3.4 Preprints and data bases

1. S. Albeverio, K.A. Makarov, and A.K. Motovilov, “Graph subspaces and the spectral shift function”, *LANL e-print math.SP/0105142*.

2. V.B. Belyaev, N.V. Shevchenko, S.A. Rakityansky, W. Sandhas, and S. Sofianos, “Microscopic description of $\eta$-photoproduction on light nuclei”, *LANL e-print nucl-th/0108022*.

3. M. Kohl, P. Bartsch, D. Baumann, J. Bermuth, R. Bohm, K. Bohinc, S. Derber, M. Ding, M.O. Distler, I. Ewald, J. Friedrich, J.M. Friedrich, P. Jennewein, M. Kahrau, S.S. Kamalov, A. Kozlov, K.W. Krygier, M. Kuss, A. Liesenfeld, H. Merkel, P. Merle, U. Müller, R. Neuhausen, Th. Pospischil, M. Potokar, C. Rangacharyulu, A. Richter, D. Rohe, G. Rosner, H. Schmieden, G. Schrieder, M. Seimetz, S. Širca, T. Suda, L. Tiator, M. Urban, A. Wagner, Th. Walcher, J. Wambach, M. Weis, and A. Wirzba, “Self energies of the pion and the Delta isobar from the $He^3(e,e'\pi^+)H^3$ reaction,” *LANL e-print nucl-ex/0104004* (Submitted to Phys. Rev. Lett.)

4. V. Hardt, R. Mennicken, and A.K. Motovilov, “Factorization theorem for the transfer function associated with an unbounded non-self-sdjoint $2\times2$ operator matrix”, *LANL e-print math.SP/0109095*.

5. N.V. Shevchenko, V.B. Belyaev, S.A. Rakityansky, S.A. Sofianos, and W. Sandhas, “Coherent photoproduction of $\eta$ mesons on three nucleon systems”, *LANL e-print nucl-th/0108031*.

### 3.5 Conference contributions

1. R.A. Arndt, I. Aznauryan, R.M. Davidson, D. Drechsel, O. Hanstein, S.S. Kamalov, A.S. Omelaenko, I. Strakovsky, L. Tiator, R.L. Workman, and S.N. Yang, "Multipole analysis of a benchmark data set for pion photoproduction", Summary of the Partial Wave Analysis Group of the BRAG Workshop, 5–6 March 2001, Mainz, Germany. *LANL e-print nucl-th/0106059*.

2. V.B.Belyaev et al., "Microscopic description of $\eta$-photoproduction on light nuclei", "Mesons and light nuclei", Prague, 2001.

3. S.S. Kamalov, D. Drechsel, L. Tiator, and S.N. Yang, "Multipole analysis for pion photoproduction with MAID and a dynamical models," Workshop on the Physics of Excited Nucleons (NSTAR 2001), 7–10 March 2001, Mainz, Germany. *LANL e-print nucl-th/0106045*.

4. A.V. Matveenko, "Diagonalization of the Coriolis couplings", XX-ICPEAC, 18–24 July 2001, Santa Fe, New Mexico, USA.

5. A.V. Matveenko, "He-trimer bound rotational states", $\mu$CF01, 22–26 April 2001, Shimoda, Japan.

6. F.M. Pen'kov, "Resonance transparency of barriers for structural particles", The Third International Conference "Nuclear and Radiation Physics", 4–7 June 2001, Almaty, Kazakstan.

7. L. Tiator, D. Drechsel, S.S. Kamalov, and S.N. Yang, "Recent progress in pion photo and electroproduction analysis", The 9th International Symposium on Meson–Nucleon Physics and the Structure of the Nucleon (MENU 2001), 26–31 Jul 2001, Washington D. C., USA. *LANL e-print nucl-th/0111062*.

8. S.N. Yang, G.Y. Chen, S.S. Kamalov, D. Drechsel, and L. Tiator, "Recent developments in the dynamical and unitary isobar models for pion electromagnetic production," Workshop on the Physics of Excited Nucleons (NSTAR 2001), 7–10 March 2001, Mainz, Germany. *LANL e-print nucl-th/0106027*.

## 4 Sector seminars in 2001

1. Pen'kov F.M. "Use of an Effective Field Theory (EFT) in Three-Body Problems".
2. Pupyshev V.V., "Some expansions in the three-body problems".
3. Chabanov V.M. and Zakhariev B.N., "A resonance total (100%) reflection and new aspects of resonance tunneling" (joint with the Seminar on Nuclear Theory).
4. Flin P., "Testing the theories of large scale structure origin" (joint seminar of BLTP Sectors 11 and 4.)
5. Kamalov S.S., "Medium effects in nuclear reactions with pions and kaons" (joint with the Seminar on Nuclear Theory.)
6. Chuluunbaatar O., Puzynin I.V., Pavlov D.V., Gusev A.A., Larsen S.Y., and Vinitsky S.I., "Iteration schemes for solving the multichannel scattering problem".
7. Shevchenko N.V. "Interaction of $\eta$-mesons with light nuclei".

Also see Sector's Seminars Board for 2001 at http://thsun1.jinr.ru/perl-cgi/seminar_fb.pl?2001.

# 5 Visits

## 5.1 Conferences, schools

1. V.B. Belyaev, International conference “Mesons and and light nuclei”, Prague, 2–6 July 2001.

2. S.S. Kamalov, Workshop on the Physics of Excited Nucleons (NSTAR 2001), Mainz, Germany, 7–10 March 2001,

3. M. Khankhasayev, Meeting for the NATO/CCMS Pilot Study on Environmental Decision Making for Sustainable Development in Central Asia, Istanbul, Turkey, 26 February – 1 March 2001.

4. M. Khankhasayev, Joint U.S./Russian JCCEEM Deactivation and Decommissioning Workshop and Demonstration of the NIKIMT-Developed Gamma Locator Device, Idaho National Engineering and Environmental Laboratory (INEEL), Idaho Falls, Idaho, USA, 10 July 10 – 2 August 2001.

5. M. Khankhasayev, Joint U.S./Russian Workshop on Contaminant Transport Modeling and Site Characterization, San Francisco, USA, 10–14 December 2001.

6. A.V. Matveenko, XX-ICPEAC, Santa Fe, New Mexico, USA, 18–24 July 2001.

7. A.V. Matveenko, $\mu$CF01, Shimoda, Japan, 22–26 April 2001.

8. N.V.Shevchenko, Third International Conference “Perspectives in hadronic physics”, Miramare-Trieste, Italy, 7–11 May 2001.

9. F.M. Pen’kov, The Third International Conference “Nuclear and Radiation Physics”, Almaty, Kazakstan, 4–7 June 2001.

### 5.2 Collaboration visits

1. V.B.Belyaev, Theoretical Physics Department, KFKI, Budapest, Hungary, 20.09–31.10.2001
2. S.S. Kamalov, Institute of Nuclear Physics, Mainz University, Mainz, Germany, 01.02.2001–11.03.2001
3. S.S. Kamalov, Taipei National University, Taipei, Taiwan, 02.04.2001–30.06.2001
4. S.S. Kamalov, George Washington University, Washington D.C., USA, 15.09.2001–10.10.2001
5. S.S. Kamalov, Institute of Nuclear Physics, Mainz University, Mainz, Germany, 11.10.2001–11.11.2001
6. A.V. Matveenko, University of Mainz, Germany, 19.11–15.12.2001.
7. D.E. Monakhov, Department of Physics, University of South Africa, Pretoria, South Africa, 1.02.2001–31.01.2002
8. A.K. Motovilov, Institute for Applied Mathematics, University of Bonn, Bonn, Germany, 12.03–11.07.2001
9. A.K. Motovilov, Department of Mathematics, University of Regensburg, Regensburg, Germany, 06.05–11.05.2001
10. F.M. Pen'kov, Institute for Nuclear Physics, Almaty, Kazakstan, 2.06–8.06.2001.

## 6 Visitors

1. J. Revai, Theoretical Physics Department, KFKI, Budapest, Hungary (May, 2001)
2. S.A. Rakityansky, Physics Department, UNISA, Pretoria, South Africa (June, November 2001)