3rd Almaty International Workshop

Nuclear Physics & Astrophysics Book of Abstracts

14-16 April, 2016

al-Farabi KazNU

Program and abstracts

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"Nuclear Physics and Astrophysics"
14-16 April, 2016
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Almaty, Kazakhstan

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Physical-Technical Faculty
Institute of Experimental and Theoretical Physics

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Takibayev N.Zh., Kurmangaliyeva V .O., Duisebai A.D.

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III INTERNATIONAL WORKSHOP
"NUCLEAR PHYSICS AND ASTROPHYSICS"
APRIL 14-16, 2016, Almaty, Kazakhstan
al-Farabi Kazakh National University
Physical-Technical Faculty, The Chair of Theoretical and Nuclear Physics,
Institute of Experimental and Theoretical Physics

The International Workshop "Nuclear Physics and Astrophysics", organized by the Chair of Theoretical and Nuclear Physics, Physical-Technical Faculty and the Institute for Experimental and Theoretical Physics of the al-Farabi Kazakh National University will take place on April 14 – 16, 2016 at the Physical-Technical Faculty of the al-Farabi Kazakh National University, Almaty, Kazakhstan.

Co-organizers: Institute of Nuclear Physics of the Republic of Kazakhstan, National Center for Space Research and Technologies, Fesenkov' Astrophysical Institute, Almaty, Kazakhstan

Workshop Language - English. All reports, abstracts and papers accepted for publication are to be in English. The papers for publication in the journal abroad will be peer reviewed.

International Organizing committee: Bum-Hoon Lee (Asia Pacific Center for Theoretical Physics, Republic of Korea), Kiyoshi Kato (Hokkaido University, Japan), Shinsho Oryu (Tokyo University of Science, Japan), Roman Kezerashvili (New-York City University, USA), V.S. Vasilevsky (Bogolyubov Institute for Theoretical Physics, Ukraine), R. Ruffini (ICRANET Sapiensa, University of Roma, Italy), K. Spitaleri (University of Catania, Italy), Chingis Omarov (National Center of Space Researches and Technologies; Fesenkov' Astrophysical Institute, Almaty, Kazakhstan), S. Sakhiev (Institute of Nuclear Physics, Almaty, Kazakhstan), V.N.Melnikov (Russia, MSU, RUDN), T. S. Ramazanov, T.A. Kozhamkulov, A.E. Davletov, M.E.Abishev, N.Takibayev (al-Farabi KazNU, Almaty, Kazakhstan).

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Please, send to the scientific secretary of the Organizing committee (E-mail: venera_baggi@mail.ru) the names of the authors, titles and abstracts of your talks (not more than 1 page for one report). The deadline for abstract submission is extended up to March 24, 2016.

The International Workshop will cover areas like nuclear cluster physics, few-body systems, light nuclei and nuclear reactions in astrophysics, physics of neutron stars and white dwarfs, galaxies and other aspects of modern problems of nuclear physics and astrophysics.

Venue: Conference room – room № **330**, Physical-Technical Faculty, al-Farabi KazNU, av. al-Farabi 71, Almaty

Program of III International Workshop "Nuclear Physics and Astrophysics"

Date: 14 April 2016

Time table

09:00 – 09:30	Registration of participants.
09:30 – 09:45	**Opening ceremony**
	Section 1. Nuclear Physics (Theory)
09:50 – 10:20	V.S. Vasilevsky, K. Katō, et al; "Formation and decay of resonance states in ^{9}Be and ^{9}B nuclei. Microscopic three-cluster model investigations"
10:20 – 10:50	R. Otani, M. Iwasaki, M. Nakao, and M. Ito; "Cluster structures in unbound states of ^{19}Ne"
10:50 – 11:20	K. Kato, M. Odsuren, et al.; "Photodisintegration and Virtual State in the Complex Scaling Method"
11:20 – 11: 40	Coffee-break
	Section 2. Nuclear Physics (Experiments)
11:40 – 12:10	S. Yamaki, K. Morimoto, D. Kaji, et al; "Current status of superheavy element search in the GARIS-II facility at RIKEN"
12:10 – 12: 40	Daiki Nishimura, K. Aoki, T. Nagai, et al, "Half life measurement of isomeric state in ^{25}Si"
12:40 – 14:00	Break for Lunch
	Section 3. Nuclear Astrophysics
14:00 – 14:30	Claudio Spitaleri; "The puzzle of electron screening in Nuclear Astrophysics: a nuclear solution?"
14:30 – 15:00	V. S. Vasilevsky, N. Zh. Takibayev, A. D. Duisenbay; "Influence of the cluster polarization on spectrum and reactions in mirror ^{8}Li and ^{8}B nuclei"
15:00 – 15:30	Nurgali Takibayev; "Forced Reverse Reactions in the Neutron Star Matter"
15:30 – 16:00	Coffee-break
	Section 4. Nuclear Physics (experiments)
16:00 – 16:20	N.Burtebayev, Zh.K.Kerimkulov, D.K.Alimov, et al; "Elastic scattring of ^{3}He ions on ^{14}N at energies near the coulomb barrier"

16:20 – 16:40	Marzhan Nassurlla, N. Burtebayev, et al; “The process of scattering of 13C ions on 12C nuclei at energies close to the Coulomb barrier”
16:40 – 17: 00	Daniyar Janseitov, N. Burtebayev, et al; “Elastic scattering of ^{3}He ions from ^{13}C nuclei in optical and folding models”

Program of III International Workshop “Nuclear Physics and Astrophysics”

Date: 15 April

Time table	**Section 5. Astrophysics**
09:00 – 09:30	Ernazar Abdikamalov, (Nazarbayev University); “Probing Core-Collapse Supernova Central Engine with Gravitational Waves”
09:30 – 10:00	Daniele Malafarina, (Nazarbayev University); “Bounces and exotic compact objects from gravitational collapse; Analytical insights into the strong field regime”
10:00 – 10:10	N. Burtebayev[1], Y. Mukhamejanov[1] “Elastic and inelastic ^{11}B+d scattering”
10:10 – 10:20	N. Burtebayev1, N.V. Glushchenko “Analysis of elastic and inelastic scattering of ^{3}He ions on ^{9}Be nuclei at energy 60 MeV”
10:20 – 11:00	Coffee-break
	Section 6. Nuclear Physics (Theory)
11:00 – 11:30	P. Krasovitsky, F. Pen’kov (INP); “Phase shifts of molecular resonance transparence”
11:30 – 11:50	Zhusupov M.A., Ibraeva E.T., Kabatayeva R.S.; “Inelastic Proton Scattering on the Ground and Excited States of ^{9}Be Nucleus in the Framework of the Diffraction Multiple Scattering Theory”
11:50 – 12:20	M. Abishev (al-Farabi KazNU); “On cyclic reactions under thermal neutrons flux”
12:20 – 13:40	Break for Lunch
	Section 7. Physics and Astropysics
13:40 – 14:00	V.N.Melnikov (Russia, MSU, RUDN) to be announced

14:00 – 14:10	S.Kumekov “The dynamics of electron-hole plasma in the semiconductor excited by high power light pulses”
14:10 – 14:20	S.Kunakov “To the theory of electrostatic probe in dusty plasma, generated by a volume source of fission fragments”
14:20 – 14:30	F.Sagimbaeva “Application of sum coincidence corrections for study of reaction rate of residual nuclei in fission and spallation”
14:30 – 14:40	B.Baimurzinova “Analyzing power of Inverse Diproton Photodisintegration at Intermediate Energies”
14:40 – 14:50	V. Dzhunushaliev, Makhmudov A., Urasalina A.; “Phantom compact and extended objects in astrophysics”
14:50 – 15:00	Z.Zh.Zhanabaev “Fractal - geometric description of the "distance - speed" chart for antigravitating galaxies”
15:00 – 18:00	**Excursions along Esentai river, The region of Theaters and Sport Palaces, Visiting Kasteev museum**

Program of III International Workshop “Nuclear Physics and Astrophysics”

Date: 16 April

Time table	**Section 8 Round-Table (Part 1)**
09:30 – 10:00	M. Abishev (al-Farabi KazNU), S. Kumekov (KazNTU), A. Davletov, K. Kato (Hokkaido University), et al.
	Skype-section (Part 1)
10:00 – 10:40	H. Quevedo (National Autonomous University of Mexico and University of Rome) “Multipole structure of compact objects”
10:40 – 11:00	K. Boshkayev (al-Farabi, KazNU) “Observational and theoretical constraints on the mass-radius relations of neutron stars”
	Section 8 Continuation of Round-Table (Part 2):

11:00 – 12:00	**Perspectives and new collaborations** (M. Abishev, N. Takibayev, K. Kato, et al)
	Continuation of Skype-section (Part 2):
12:00 – 12:30	Yuliya Lashko, G. Fillipov, et al., "Dynamics of two-cluster systems in phase space"
12:30 – 12: 45	Roman Kezerashvili (University of New York City,USA), "Lightest Kaonic Nuclear Clusters"
12:45 – 13:00	**Closing of III International Workshop "Nuclear Physics and Astrophysics"**

Formation and decay of resonance states in ^{9}Be and ^{9}B nuclei. Microscopic three-cluster model investigations

V. S. Vasilevsky[1], K. Katō[2], N. Zh. Takibayev[3]

[1]*Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine*
[2]*Nuclear Reaction Data Centre, Faculty of Science, Hokkaido University, Sapporo, Japan*
[3]*Al-Farabi Kazakh National University, Almaty, Kazakhstan*

Resonance state is one of the challenging problems for theoretical and nuclear physics. There are common features of resonance states, observed in few- or many-channel systems. However, there are some specific features connected with the way of excitation or generation of resonance states and also in different way of resonance state decay in nuclear systems. Special attention is attracted by resonance states formed by three interacting clusters, i.e. resonance states embedded in three-cluster continuum. Such resonance states are repeatedly observed in nuclei with well-determined three-cluster structure. These nuclei have dominant three-cluster configuration, it means that bound states and many resonance states are lying bellow and above, respectively, threshold of three-cluster continuum. As an example of such nuclei, we can mention ^{5}H, ^{6}He, ^{6}Be, ^{9}Be and ^{9}B and many others.

The aim of the present report is to study low-energy spectrum of mirror nuclei ^{9}Be and ^{9}B. Investigation of low-lying states in ^{9}Be is interesting for astrophysical applications and, in particular, for problem of synthesis and abundance of light nuclei in the Universe. We microscopic method, which employs hyperspherical harmonics to numerate channels of three-cluster continuum and was formulated in [1], allow us to determine energy and width of a resonance state, reveal the dominant decay channels, and shed more light on nature of resonance state by analyzing its wave functions.

Results, presented in this report, are obtained with the modified version of the Hasegawa-Nagata potential, which is often used in calculation of two- and three-cluster structure of light nuclei. It is shown the three-cluster model with such potential reproduces fairly good spectrum of resonance states in both nuclei. By calculating and comparing spectrum of excited states in mirror nuclei ^{9}Be and ^{9}B, we are able to determine effects of the Coulomb interaction. It is shown that energy and width of resonance state in ^9B is larger than corresponding parameters in its counterpart in ^9Be. We found three groups of resonance states in these nuclei. They reveal small, medium and strong effects of the Coulomb interaction. Special attention is paid to the controversial $½^+$ states in ^9Be and ^9B. It is show that within our model, these states are relatively wide resonance. These states are located not far from the three-cluster threshold and they prefer to decay on ^5He (^5Li) and alpha particle in the channel with zero orbital momentum. There is Coulomb barrier in this channel which determines energy and width of the $½^+$ resonance states. We also analyze all resonance states in ^9Be in order to find the Hoyle-analogue state. We suggested that the $5/2^-$ resonance state can be considered as the Hoyle-analogue state as this is very narrow resonance state. It lives long enough and may transform to the $3/2^-$ ground state of ^9Be by emitting the quadrupole gamma quanta. This reaction, which involves the triple collision of two alpha particles and neutron and subsequent radiation of gamma quanta, can be considered as an additional way for synthesis of ^9Be nuclei.

Reference:

[1] V. Vasilevsky, A.V. Nesterov, F. Arickx, J. Broeckhove, Algebraic model for scattering in three-s-cluster systems. I. Theoretical background. Phys. Rev. C, 63, 034606, 2001.

Cluster structures in unbound states of ^{19}Ne

R. Otani, M. Iwasaki, M. Nakao, and M. Ito

Department of Pure and Applied Physics, Kansai University, 3-3-35; Yamatecho, Suita, Osaka 564-8680, Japan.

Cluster structures are well known to appear in the excited states of light nuclear systems. A typical example can be seen in ^{20}Ne. The α + ^{16}O cluster model is successful in reproducing the ground and excited rotational band structures in ^{20}Ne [1]. In ^{19}F, which is one proton deficient system of ^{20}Ne, the formation of the α + ^{15}N cluster structures are deeply analyzed [2; 3]. On the contrary, the α + ^{15}O cluster structure, corresponding to the neutron deficient system of ^{20}Ne, still remains unclear although the pioneering works can be seen in Refs. [2; 3]. The unbound continuum states of this cluster structure is expected to be important in the radiative capture reaction of ^{15}O(α, γ)^{19}Ne, which plays the crucial role in the advanced stage of the Hydrogen burning [4].

In the present study, we investigate the cluster structure in ^{19}Ne by applying the microscopic cluster model, the generalized two-center cluster model (GTCM) [5], which can handle the chemical-bonding structure in general two-center nuclear systems. This model has been applied to Be isotopes, and it has been successful in describing the structure and reaction problems [5]. We have solved the coupled-channels equations of (^{3}He + ^{15}O) + (α + ^{16}O) in the framework of GTCM. Above the α decay threshold, the absorbing boundary condition (ABC) [6] is applied to identify the resonant levels. The GTCM calculation nicely reproduce the qualitative feature of the low-lying bound levels in ^{19}Ne. Furthermore, the GTCM calculation under the ABC predicts the resonant levels above the α threshold. We have also calculated the resonant level by employing the α + ^{15}O potential model [7], and their results are compared to those of the microscopic GTCM calculation.

In the radiative capture reaction of ^{15}O(α, γ)^{19}Ne at the astrophysical energy region, the most crucial resonance is known to arise through the $J^{\pi} = 3/2^{+}$ resonant level at 504 keV with

respect to the α + ^{15}O threshold (E_x = 4.03 MeV). According to the previous studies on the mirror system of ^{19}F [2; 3], any cluster model calculations cannot reproduce the respective $3{=}2^{+}$

state, which exists just below the α threshold. The analyses in Ref. [4] have pointed out that the intrinsic structure of the resonance at 504 keV in ^{19}Ne is not the α + ^{15}O cluster structure but the five particle - two hole (5p - 2h) shell-model configuration with the $^{14}O_{g:s:}$ core. However, there is no shell model calculation which takes into account the 5p-2h configurations. The 5p-2h configuration has a large overlap with the shell model limit of the ^{5}He + ^{14}O configuration. Therefore, the coupling of ^{5}He + ^{14}O on the $J^{\pi} = 3/2^{+}$ state is essential in the cluster model approach. In the present study, we have performed the extended coupled-channels calculation of (^{3}He + ^{16}O) + (α + ^{15}O) + (^{5}He + ^{14}O) and found that a new $3/2^{+}$ level appears around the α threshold. This level is generated by the coupling of the ^{5}He + ^{14}O configuration. The details of the present calculation will be reported.

References:

[1] Andra T. Kruppa, and K. Kato, Prog. Theor. Phys. 84 (1990) 1145, and references therein.

[2] T. Sakuda and F. Nemoto, Prog. Theor. Phys. 62 (1979) 1274.

[3] P. Descouvemont and D. Baye, Nucl. Phys. A463, 629, (1986).

[4] Z. Q. Mao et al., Phys. Rev. Lett. 74 (1995) 3760, and references therein.

[5] M. Ito and K. Ikeda, Rep. Prog. Phys. 77 (2014) 096301.

[6] M. Ito and K. Yabana, Prog. Theor. Phys. 113 (2005) 1047.

[7] R. Otani et al., Phys. Rev. C 90 (2014) 034316.

Photodisintegration and Virtual State in the Complex Scaling Method

K. Kato[1], M. Odsuren[1], Y. Kikuchi[1], T. Myo[1], V. S. Vasilevsky[2] and N. Takibayev[3]

[1]Nuclear Reaction Data Centre, Faculty of Science, Hokkaido University, Sapporo, Japan
[2]Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine
[3]Al-Farabi Kazakh National University, Almaty, Kazakhstan

It is a longstanding problem to determine its resonance energy and width of the first excited $1/2^+$ state of ^{9}Be, which is closely connected with the problem to clarify whether it is a resonant state or not. Recently, we studied the $1/2^+$ state of ^{9}Be and the photodisintegration cross section (PDXS) applying the complex scaling method (CSM) to the α+α+n three-cluster model. The results indicate that there is no sharp resonant state corresponding to the distinguished peak observed just above the ^{8}Be+n threshold in the photodisintegration cross section of ^{9}Be. On the other hand, the recent experimental cross section data can be well explained by the α+α+n calculation. From these results, we concluded that the first excited $1/2^+$ state in ^{9}Be is a ^{8}Be+n virtual state but not resonant one.

The virtual states in nuclear systems have been discussed in the T = 1 states of two-nucleon systems for a long time, and recently again much interest is acquired in association with weak binding problems of neutron rich nuclei. The low energy photodisintegration reaction of ^{9}Be has also received much attention from the viewpoint of the astrophysical interest. The cross section of the photodisintegration has been discussed to be negligibly small in the energy region between thresholds of $\alpha + \alpha + n$ (1.5736 MeV) and ^{8}Be+n (1.6654 MeV). The observed cross section above the ^{8}Be+n shows a prominent peak, although there are some discrepancies among the experimental absolute values. The cross section profile has an asymmetric character and cannot be explained by a simple resonance formula like the Breit-Wigner form.

We investigate the cross section form of the photodisintegration and the phase shift behavior of a virtual state assuming a simple two-body model. The CSM has been shown to be a very powerful framework to solve the resonance poles of the many-body *S*-matrix. In the previous paper, the two-body scattering phase shifts are presented to be described by the eigenvalues of the complex scaled Hamiltonian. However, a case of virtual states was not included because the isolated virtual-state eigenvalues cannot be solved in the CSM. Although there is no isolated solution, it is shown that the photodisintegration of the virtual state can be described using the complex scaled continuum (CSC) states. This result suggests the scattering phase shifts of virtual states can bee also calculated with the CSM, and it is expected that the virtual states characterization can be investigated through the PDXS of the two-body system in detail.

Current status of superheavy element search in the GARIS-II facility at RIKEN

S. Yamaki[1,2], K. Morimoto[1], D. Kaji[1], Y. Wakabayashi[1], M. Takeyama[1,3]; K. Tanaka[1,4], H. Baba[1], T. Yamaguchi[2], T. Suzuki[2], and K. Morita[1,5]

[1] Nishina Center, RIKEN, Wako, Saitama 351-0198, Japan; [2] Dep. of Phys., Saitama Univ., Saitama 338-8570, Japan; [3] Grad. Sch. of Sci. and Eng., Yamagata Univ., Yamagata 990-8560, Japan; [4]Fac. of Sci. and Tech., Tokyo University of Science, Chiba 278-8510, Japan; [5] Dep. of Phys., Kyushu Univ., Fukuoka 819-0395, Japan

The project to synthesize the 113th element by the reaction ^{209}Bi + ^{70}Zn → ^{278}113 + n started at RIKEN in 2003. Three decay chains started from ^{278}113 were observed in 2004, 2005, and 2012 [1-3]. This project had come to an end with the observation of 3rd decay chain. We are now focusing on searching for undiscovered superheavy elements. A series of commissioning experiments of new gas-filled separator GARIS-II [4] designed for hot fusion reaction has been almost completed.

The half-lives of superheavy nuclei are predicted by several theoretical calculations where mass formulae indicate that the half-lives will be in an order of microseconds for some nuclei with Z heavier than 120 [5, 6]. The decay energies and decay times of such short-lived nuclei are difficult to measure with existing system because of pileup phenomena. To overcome this difficulty, a digital data acquisition system with flash-ADC was implemented to the GARIS-II reading out system. Here, waveforms from the pre-amplifier are directly registered with flash-ADC. Then the pulse shape analysis is applied for the waveforms [7].

In this contribution, a review of current status of new element search and the development of the new data acquisition system with flash-ADC and pulse shape analysis will be presented.

References:

[1] K. Morita et al., J. Phys. Soc. Jpn. 73 (2004) 2593.
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Half-life measurement of isomeric state in ^{25}Si

D. Nishimura[1], K. Aoki[1], T. Nagai[1], Y. Takei[1], A. Takenouchi[1], M. Fukuda[2], J. Chiba[1], K. Chikaato[3], Du[2], S. Fukuda[4], A. Ikeda[3], T. Izumikawa[5], S. Kanbayashi[2], N. Kanda[3], Y. Kanke[1], I. Kato[6], A. Kitagawa[4], M. Machida[1], M. Mihara[2], E. Miyata[3], J. Nagumo[1], K. Nishizuka[3], S. Ohmika[6], K. Ohnishi[2], T. Ohtsubo[3], H. Oikawa[1], S. Sato[4], T. Sugihara[2], T. Suzuki[6], N. Tadano[6], H. Takahashi[3], M. Takechi[3], M. Tanaka[2], Y. Tanaka[2], S. Yagi[1], T. Yamaguchi[6], S. Yamaoka[2], and K. Yokoyama[3]

[1]Department of Physics, Tokyo University of Science, Noda, Chiba 278-8510, Japan; [2] Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan; [3]Department of Physics, Niigata University, Niigata 950-2102, Japan; [4]National Institute of Radiological Sciences, Chiba 263-8555, Japan;
[5]RI Center, Niigata University, Niigata 950-8510, Japan
[6]Department of Physics, Saitama University, Saitama 338-8570, Japan

The rapid proton capture process (rp-process) passing through proton-rich nuclei plays an important role in the nucleosynthesis as well as the rapid neutron capture process (r-process). However, a possible path of the rp-process ^{24}Al(p,γ)^{25}Si(p,γ)^{26}P(p,γ)^{27}S has not been well studied yet due to lack of experimental data for their nuclear structure. Since the temperature in the hydrogen burning is around 10^9 K (= ~100 keV), low-lying excited states can affect the rp-process taking into account the Maxwell-Boltzmann distribution. In the proton drip-line nucleus ^{26}P, we have recently observed an isomeric state at E_x = 164.4(1) keV and determined the half-life $T_{1/2}$ = 120(9) ns [1]. On the other hand, the first excited state at E_x = 40(5) keV in ^{25}Si, which is also a candidate for the isomer, has not been researched yet in detail. In order to measure the half-life of the first excited state in ^{25}Si, the γ-ray spectroscopy have been performed at NIRS-HIMAC.

A secondary beam including ^{25}Si was produced by the projectile fragmentation of a 300-MeV/u primary beam of ^{28}Si on a 20-mm-thick CH_2 target. The secondary beam was separated and identified by using SB2 beamline and was implanted in an active stopper consisting of three plastic scintillators. The γ rays were measured with three kinds of detectors surrounding the stopper, four $LaBr_3$(Ce) detectors (1.5 in. x 1.5 in.), a HPGe detector (50 mm x 20 mm), and a NaI(Tl) detector (5 in. x70mm).

The delayed γ rays of 44.2(1) keV have been observed by these detectors. By fitting theγgated decay curve, the half-life has been determined to be 43(1) ns for the first time.

The transition probability deduced from the γ-ray energy and the half-life suggests M1 multipolarity with Weisskopf estimation. Since the excitation energy and the half-life of this state are similar to those of the first excited state (J^{π}= $3/2^{+}$, E_x = 89.53 keV, $T_{1/2}$ = 5.1(3) ns) in T = 3/2 mirror nucleus ^{25}Na, the spin-parity of the isomeric state in ^{25}Si is probably assigned as $3/2^{+}$.

Reference:

[1] D. Nishimura *et al.*, EPJ Web of Conferences 66, 02072 (2014).

The puzzle of electron screening and nuclear clustering

C. Spitaleri, Department of Physics and Astromomy, University of Catania, Catania, Italy and INFN-Laboratori Nazionali del Sud, Catania, Italy.* C. A. Bertulani, Department of Physics and Astromomy, Texas A&M University-Commerce, Commerce, TX 75429, USA; L. Fortunato and A. Vitturi, Dipartimento di Fisica e Astronomia "Galileo Galilei", Universita` di PadovaPadova, Italy and INFN, Sezione di Padova, Padova, Italy

Accurate measurements of nuclear reactions of astrophysical interest within, or close to, the Gamow peak, show evidence of an unexpected effect attributed to the presence of atomic electrons in the target. The experiments need to include an effective "screening" potential to explain the enhancement of the cross sections at the lowest measurable energies (1).

Despite various theoretical studies conducted over the past 20 years and numerous experimental measurements, a theory has not yet been found that can explain the cause of the exceedingly high values of the screening potential needed to explain the data.

In this talk will be presented that instead of an atomic physics solution of the "electron screening puzzle", the reason for the large screening potential values is in fact due to clusterization effects in nuclear reactions, in particular for reaction involving light nuclei (2).

References:

[1] C. Rolfs, W. Rodney, Cauldrons in the Cosmos, The University of Chicago, 1988, p. 561.

[2] C. Spitaleri, C. A. BertulaniL. Fortunato and A. Vitturi Physics Letters B 755 (2016) 275.

Influence of the cluster polarization on spectrum and reactions in mirror ^{8}Li and ^{8}B nuclei

V. S. Vasilevsky[1], N. Zh. Takibayev[2], A. D. Duisenbay[2]
[1]Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine
[2]Al-Farabi Kazakh National University, Almaty, Kazakhstan

Analysis of the astrophysical data on the abundance of light atomic nuclei in the Universe stimulated new and more detail experimental and theoretical investigations of reactions induced by interaction of light nuclei. For the astrophysical applications one has to know the cross section of a reaction at the low energy region, which amounts several keV in the entrance channel of the reaction. This region of energy can be easily achieved at experimental facilities for the reactions induced by interaction of neutrons with light nuclei. However, it is not the case for interaction of light nuclei, containing one or more protons. Coulomb interaction between nuclei makes very difficult to measure the cross section. In this case theoretical methods are invaluable tool to determine or to evaluate the cross section of importance.

As many of light nuclei are weakly bound, they could easy change their size or shape while interacting with neutrons, protons or other light nuclei. This phenomenon is called the polarization. A microscopic three-cluster model was formulated in Ref. [1] to take into account polarizability of the interacting clusters. We refer to it as "cluster polarization". It was shown in Refs [1-2] that cluster polarization plays an important role in formation of bound and resonance states in seven nucleon systems. It was also shown that cluster polarization has large impact on different types of reactions in ^{7}Li and ^{7}Be nuclei. Within the present paper, the effects of cluster polarization will be studied in light mirror nuclei ^{8}Li and ^{8}B, and interaction of neutron with ^{7}Li and proton with ^{7}Be. Both ^{7}Li and ^{7}Be nuclei have well established two-cluster structure: ^{4}He+^{3}H and ^{4}He+^{3}He, respectively. This fact is taken into account in the present model.

We consider spectrum bound and resonance states of the mirror nuclei ^{8}Li and ^{8}B within the three-cluster microscopic model. We selected several semi-realistic potentials to represent nucleon-nucleon interaction in eight-nucleon systems. Effects of the spin-orbital components of nucleon-nucleon interaction on spectrum of ^{8}Li and ^{8}B are studied in detail. Our calculations confirm that these nuclei exhibit the halo properties as a radius of proton (neutron) cloud is much smaller neutron (proton) cloud in bound states of ^{8}Li (^{8}B). It is established that cluster polarization has large impact on energy of bound states and on energy and width of resonance states. Besides, cluster polarization strongly affects phase shift and cross section of the elastic and inelastic scattering of neutrons on ^{7}Li and protons on ^{7}Be.

One of our aims is to consider how cluster polarization affects the radiative capture reactions ^{7}Li(n,γ)^{8}Li and ^{7}Be(p,γ)^{8}B. We also study correlations between parameters of the bound states and the astrophysical S-factor of the reactions.

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Forced reverse reactions in neutron star matter

Nurgali Takibayev
Al-Farabi Kazakh National University, Almaty, Kazakhstan

Nuclear reactions and processes that occur in neutron star envelopes were considered in the frame of their mutual influences. Most part of these are stimulated by over dense matter and transformed to exotic states, which cannot appear in ordinary terrestrial conditions or in laboratory experiments. It was shown the important roles of forced reverse reactions and nonlinear interactions as well as few-body effects and actions of ordering crystalline structures in forming of these states. Remarkable that the chemical composition of primordial matter of a neutron star determines the evolution of the neutron star matter and peculiarities of nuclear reactions and processes. For example, the neutron resonances of few-body type that arise in crystalline structure have the selected character and take place only in suitable layers that lead to local oscillations of density. The nonlinear interactions can result to reactions with gammas, which knockout alpha particles from the nuclei. Then the inner crust layers will be enriched with free neutrons and alpha particles also. The calculations demonstrate cardinal distinction between the processes of isotope transformation in the case of Fe group and the element transformation of Al group.

Elastic scattering of ^{3}He ions on ^{14}N at energies near the coulomb barrier

N.Burtebayev[1], Zh.K.Kerimkulov[1], D.K.Alimov[1,2], A.V.Yushkov[2], Y.S.Mukhamejanov[2], D.M.Janseitov[3], A.N.Bahtibayev[4], A.Patteyev[4]

[1]INP, Almaty, Kazakhstan, [2]KazNU, Almaty, Kazakhstan, [3]ENU, Astana, Kazakhstan,
[4]IKTU, Turkestan, Kazakhstan; e-mail: diliyo@mail.ru

Analysis of scattering data within the optical model is the main source of information about potentials of the nucleus-nucleus interaction. It is well known, however, that for complex projectiles with $A \geq 2$, such analysis is ambiguous. An especially complicated situation occurs at low energies (E < 10 MeV/nucleon). Numerous studies have shown that the ambiguity in the extracted parameters of the real part of the nuclear potential can be both continuous and discrete. The aim of this work is to study the elastic and inelastic scattering of α-particles and ^{3}He on ^{14}N nuclei at energies of 50 - 60 MeV, i.e., where the nuclear rainbow effects begin to manifest themselves clearly. These energies are sufficiently high to avoid the worst complications of compound nuclear effects [1,2].

The measurements were carried out with beams of ^{3}He from the isochronous cyclotron U-150M of the Institute of Nuclear Physics (Almaty, Kazakhstan). The energy of ^{3}He ions were 50 and 60 MeV. A gas target was used in the experiment. It is a cylindrical cell filled with natural nitrogen (99.61% of ^{14}N) to a pressure of about 1 atmosphere. The effective thickness of the target was in the range from 1 to 7 mg/cm^2, depending on the measurement angle. The uncertainty in the estimation of the thickness was not more than 3%. In more detail, the target design is described in [3].

Scattered particles were detected by a counter telescope consisting of two silicon detectors with thicknesses of 100 microns (ΔE) and 2 mm (E). The α-particles and ^{3}He were separated from other charged products of nuclear reactions by means of two-dimensional analysis technique (ΔE-E). The total energy resolution was ranged from 400 to 500 keV, depending on the scattering angle, and determined mainly by the spread of the beam energy and the target thickness.

Differential cross sections for elastic scattering have been measured in the range of angles from 10° to 170° in the laboratory system. Angular distributions, as can be seen from the figures shown in the next section, have a diffractive structure up to angles 60° – 70°. With increasing angle this structure decays and is replaced by a broad maximum with a further fall-off at larger angles without pronounced oscillations. The statistical uncertainties of the measured differential cross sections are less than 10%.

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The process of scattering of ^{13}C ions on ^{12}C nuclei at energies close to the Coulomb barrier

N. Burtebayev [1], J.T. Burtebayeva [1], A. Duisebayev[1], T. Zholdybayev[1], Maulen Nassurlla [2],Marzhan Nassurlla[2], S.B. Sakuta [3], S. Kliczewski[4], E. Piasecki[4], K. Rusek[5], A. Trzcińska[5], M. Wolińska-Cichocka[5], S.V. Artemov [6]

[1]Institute of Nuclear Physics, Almaty, Kazakhstan; [2]Al-Farabi Kazakh National University, Almaty, Kazakhstan; [3]National Research Center "Kurchatov Institute", Moscow, Russia; [4]H. Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland; [5]Heavy Ion Laboratory of Warsaw University, Warsaw, Poland; [6]Institute of Nuclear Physics, Tashkent, Uzbekistan

The neutron transfer mechanism is responsible for the cross section increase at backward hemisphere of angles in the elastic scattering $^{12}C(^{13}C,^{12}C)^{13}C$. In this context, study of the cross sections in this area is of great interest for astrophysics since it allows us to estimate cross sections of the possible radiation capture $^{12}C(n, \gamma)\ ^{13}C$ reaction and its role in the evolution of the Universe immediately after the Big-Bang. Previously elastic scattering $^{12}C + {}^{13}C$ at an energy close to our, was investigated in limited range of angles up to 60^0 [1]. In present work the angular range extended substantially (up 120^0 in the center mass system). Differential cross sections for elastic and inelastic scattering of ^{13}C ions on the ^{12}C nuclei were measured using a beam extracted from the Cyclotron K = 160 HIL (Warsaw University) at the energy 2.5 MeV/nucleon (see the figure).The experimental data on elastic and inelastic scattering have been analyzed within the framework of the optical model (OM) and the Coupled Reaction Channels (CRC) method with code FRESCO [2] taking into account the neutron transfer mechanism. The set of the optimal parameters are V_0=73.1 MeV, r_0=1.03fm, a_0=0.699fm, W=35.22 MeV, r_w=1.19fm, a_w=0.211fm. Additionally, were obtained the differential cross section of inelastic scattering of excited state of ^{12}C nuclei 2^+. The value of the deformation parameter δ=1.1 were extracted from the analysis of experimental data of inelastic scattering.

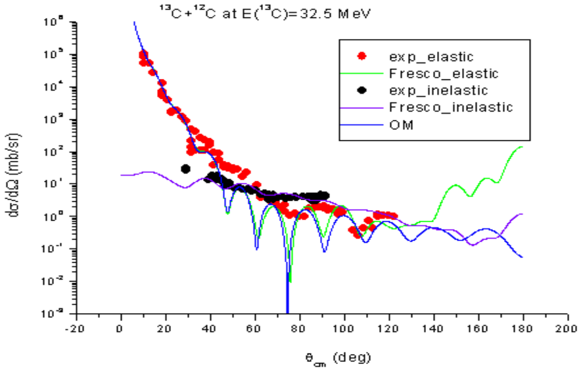

Figure: Angular distribution of the elastic scattering of ^{13}C on ^{12}C at the 32.5 MeV. The red circles are elastic experimental data while black circles are inelastic experimental data. Curves: blue line is the optical model prediction; green represents the coupled reaction channels calculation of elastic scattering by code FRESCO, violet represents FRESCO analysis of inelastic scattering.

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Elastic scattering of 3He ions from ^{13}C nuclei in optical and folding models

N. Burtebayev[1], Zh.K. Kerimkulov[1], A.S. Demyanova[2], D.M. Janseitov[3], D.K. Alimov[4], Y.S. Mukhamejanov[4], A. Shakirov[4];
[1]Institute of Nuclear Physics, Almaty, Kazakhstan, [2]NRC Kurcatov Institute, Moscow, Russia, [3]ENU, Astana, Kazakhstan
[4]KazNU, Almaty, Kazakhstan

The scattering of nucleons and complex nuclear particles (deuterons, alpha particles, heavy ions) on the nuclei is an important source of information about nuclear structure [1]. But the parameters of optical potential of interaction of particles with light nuclei at low and medium energies, derived from the analysis of differential cross sections of elastic scattering in the optical model (OM), are subject to ambiguities and require reliable estimates.

In order to obtain reliable information about the potential of nuclear interaction, obtained in a cyclotron of Institute of Nuclear Physics (Almaty, Kazakhstan), the experimental data [2] on the scattering of ions ^{3}He in ^{13}C nuclei at 50 and 60 MeV analyzed both in terms of the standard optical model with the set of potential in the parameterized form and finding its parameters by comparing the theoretical and experimental cross sections, and within a microscopic model in which the potentials are based on the effective nucleus-nucleus forces [3].

In this paper we carried out a comparative analysis of the elastic scattering of ^{3}He ions from ^{13}C nuclei in optical and folding models.

Joint analysis by standard optical model of the nucleus and folding model based on full M3Y effective interaction, allowed to eliminate the ambiguity of the optical potential. The optimal physical reasonable values of the parameters of optical potential and the normalization coefficients for the real part of folding potential are found. It is shown that both potential correlated and give a similar description of the experimental data.

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Probing Core-Collapse Supernova Central Engine with Gravitational Waves

Ernazar Abdikamalov
Nazarbayev University, Astana, Kazakhstan

Core-collapse supernovae (CCSNe) are powerful explosions of massive stars at the end of their lives, leaving behind neutron stars or black holes. CCSNe are responsible for the production of elements heavier than iron throughout the universe. Neutron stars contain nuclear matter under extreme conditions of high density, very hot temperatures, and strong magnetic fields. Some of the most pressing open questions in astrophysics, nuclear physics, and neutrino physics are posed in the context of CCSNe. Gravitational waves (GW) emitted during core-collapse supernovae open a new window into its central engine. The late collapse, core bounce, and the early postbounce dynamics of a rotating core leads to a characteristic GW signal. I will review the recent progress in modeling GW signals from CCSNe and discuss how GWs can be used to probe conditions in the cores of such supernovae.

Bounces and exotic compact objects from gravitational collapse; Analytical insights into the strong field regime

Daniele Malafarina
Nazarbayev University, Astana, Kazakhstan

We investigate how proposed modifications to general relativity in the strong field regime affect the black hole formation scenario. We show that continuous collapse is generically replaced by a bounce where the singularity doesn't form and matter re-expands after reaching an extremely compact configuration of finite size determined by the natural scale of quantum-gravity. Finally we derive the conditions for collapse to lead to the formation of a finite size exotic compact object.

Elastic and inelastic ^{11}B+d scattering

N. Burtebayev[1], Y. Mukhamejanov[1,2], Zh. Kerimkulov[1], D. Alimov[1,2], D. Janseitov[1.3], M. Nassurlla[1,2], Sh. Hamada[4]

[1] Institute of Nuclear Physics, [2] Al-Farabi Kazakh National University, Almaty, Kazakhstan; [3] Eurasian National University, Astana, Kazakhstan, [4] Faculty of Science, Tanta University, Tanta, Egypt; E-mail: y.mukhamejanov@gmail.com

Experiment on measurement of differential cross sections of elastic and inelastic scattering of deuterons from ^{11}B. was performed at deuteron beam extracted form isochronous cyclotron U-150M at Institute of Nuclear Physics (Almaty, Kazakhstan). The extracted deuterons beam has been accelerated to energies 14.5 MeV and then directed to a thin ^{11}B foil target. The measurements were carried out in a vacuum volume of the special multi-purpose scattering chamber, which included two independent ΔE-E telescopes. Each telescope consisted of two silicon semiconductor detectors. The first telescope covers angular range of small angles up to 20^0, whereas the second telescope covers angular range of 20^0-150^0 in laboratory system.

Angular distributions for elastic and inelastic scattering were obtained within angular range of 10^0-150^0 in laboratory system. The behavior of differential cross sections for these states has noticeable diffraction pattern. The data on elastic scattering were analyzed within the framework of the standard optical model of the nucleus, where the influence of inelastic channels is taken into account by introducing a phenomenological imaginary absorptive part in the interaction potential between the colliding nuclei. The theoretical calculations for the abovementioned excited states were performed using the coupled channel method implemented in computer code FRESCO [2].

The experimental data for 11B+d scattering at other energies 13.6 MeV [3] and 27.2 MeV [4] was analyzed in addition to the experimental data obtained in this experiment.

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Analysis of elastic and inelastic scattering of ^{3}He ions on ^{9}Be nuclei at energy 60 MeV

N. Burtebayev[1], S.K. Sakhiyev[1], Y. Mukhamejanov[1], N.V. Glushchenko [1], M. Nassurlla[1], B. Urazbekov[1], L.I. Galanina[2]

[1]*Institute of Nuclear Physics, Almaty, Kazakhstan*

[2]*Skobeltsyn Institute of Nuclear Physics, Moscow, Russia*

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Experimental differential cross sections of ^{3}He ions scattering on ^{9}Be nuclei at energy 60 MeV were measured at wide angular range 10^{o}-160^{o} in laboratory system at U-150M cyclotron of INP (Almaty). For both angular distributions of elastic and inelastic scattering leading to $5/2^{-}$ state (Q=2.43 MeV) one can observe noticeable enhancement of cross section at largest scattering angles.

A combined analysis of elastic and inelastic scattering within the framework of coupled reactions channel method while taking into account contributions of potential scattering and cluster transfer mechanisms allowed to reproduce the behavior of angular distributions of ^{3}He ions scattering from ^{9}Be nuclei in full angular range. The calculations were carried out using FRESCO computer code. The spectroscopic factors of ^{9}Be nucleus as "^{3}He+^{6}He" obtained from the fitting of calculated and experimental data are in agreement with the values taken from literature.

Phase shifts of molecular resonance transparence

Krassovitskiy P.M., Pen'kov F.M.
Institute of Nuclear Physics, Almaty, Kazakhstan; E-mail: pavel.kras@inp.kz

The report provides the features of resonant transition of the potential repulsive barrier by the beryllium molecule, height and width of which have the scale of the beryllium atom interaction with the crystal surface. Previously [1] the integral contribution of the resonant transition of the molecule in the physical observables has been considered. As a result, the simple formulas to evaluate this contribution have been obtained.

To expand the range of possible applications of the resonance transition effect, this work analyzes the amplitudes of transition and reflection either for elastic and inelastic processes.

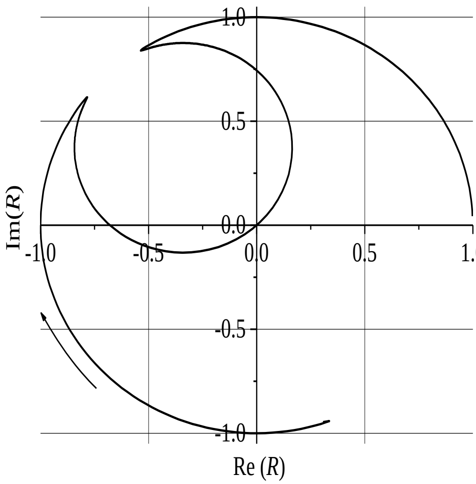

Fig. 1. The behavior of real and imaginary parts of the resonance reflection amplitude R near the resonance depending on the molecule energy. The arrow indicates the direction of the moving with the energy increase.

In particular, it is shown that the contrast of the molecular interference pattern on the crystals surface depends strongly on the energy of the molecules.

The work is being performed under the financial support of the MES RK grant 0333/GF4.

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Inelastic Proton Scattering on the Ground and Excited States of ^{9}Be Nucleus in the Framework of the Diffraction Multiple Scattering Theory

R.S.Kabatayeva[1] ,M.A.Zhusupov[1], E.T.Ibraeva[2]
[1]al-Farabi Kazakh National University, [2]Institute of Nuclear Research,
Almaty, Kazakhstan

Be^9 is a stable light nucleus, it is strongly deformed and weakly-bound in the cluster channels. The binding energy is anomalous low in three-particle $\alpha + \alpha + n$ - channel ($\varepsilon = 1.57$ MeV) and two-particle $n + Be^8$ - and $\alpha + He^5$ - channels ($\varepsilon = 1.67$ MeV and $\varepsilon = 2.47$ MeV respectively), but in two-particle $Li^8 + p$ – channel its binding energy is too high and equals $\varepsilon = 16.9$ MeV. In the ground $3/2^-$ state of this nucleus the mean-square radius equals 2.44 fm, and there is no halo structure in the ground state. But in the excited $1/2^+$ and $3/2^+$ states one observes exotic structures such as halo since their mean-square radii equals to 2.83 fm and 2.976 fm respectively and it seems that when exciting the nucleus increases in size and gains the halo structure.

Elastic and inelastic (for the $J^\pi = 1/2^+$ level) differential cross sections in the framework of the Glauber theory were calculated by the authors at E = 180 and 220 MeV and compared to the experimental data. The goal of the present study is a calculation of the differential cross section of the inelastic scattering of protons with energy of 180 MeV to the excited $J^\pi = 3/2^+$ and $5/2^-$ states of the ^{9}Be nucleus in the framework of the Glauber theory and a comparison with the results obtained in other formalisms.

The Matrix Element of Scattering in the Glauber theory is defined by the formula

$$M_{if}(\mathbf{q}) = \sum_{M_J M_J'} \frac{ik}{2\pi} \int d^2\boldsymbol{\rho} \exp(i\mathbf{q}\boldsymbol{\rho}) \delta(\mathbf{R}_A) \left\langle \Psi_f^{J'M_J'} \left| \Omega \right| \Psi_i^{JM_J} \right\rangle$$

where ρ - is an impact parameter, which is a two-dimensional vector in the Glauber theory, R_A– is a coordinate of the target nucleus mass center, Ψ – initial and final states wave functions of the target nucleus, k - are incoming and outgoing momenta of the proton, q – is a momentum transfer in the reaction, Ω – is the Glauber multiple scattering operator.

Differential cross sections of the inelastic p^9Be-scattering for the $J^\pi = 3/2^+$, $5/2^-$ levels at proton energies of 180 MeV are calculated and compared with the experimental data and with the calculation in the distorted waves method. The differential cross sections calculated in the framework of the Glauber multiple scattering theory agree with the available experimental data in the range of the forward angles for the $J^\pi = 3/2^+$ level and do not agree for the $J^\pi = 5/2^-$ level. Note that the Glauber theory has essential restrictions for energy and angle range of the particles scattered. Since the incident particles energy is not too large, then the results are reliable for forward scattering angles only. The calculation at large angles is beyond the Glauber theory accuracy.

The analysis of the profiles of the wave functions in 2αn - models showed that in the excited $J^\pi = 3/2^+$, $5/2^-$ states the nucleus has different structures: diffuse with extended asymptotic (with long tail) in the $J^\pi = 3/2^+$ state and compact with short asymptotic in the $J^\pi = 5/2^-$ state. The calculation of the mean-square radii confirms this conclusion: 2.976 fm for the $J^\pi = 3/2^+$ state and 2.13 fm for the $J^\pi = 5/2^-$ state.

The analysis of the wave functions allowed one to connect them with the behavior of the cross sections and show the influence of the contribution of the wave functions different parts on the differential cross sections.

Calculation of neutron passage through catalytic composition (pb, bi, po) by mcnp program

M.Abishev, N. Kenzhebayev and M. Khassanov
Kazakh National University named after Al-Farabi, Almaty, Kazakhstan

The purpose of this work is to verify the correctness of the catalyst composition with the numerical simulation (by MCNP program) and to calculate the passage of neutrons through this material. The passage of neutrons through the catalyst composition was modelled by MCNP program (Monte-Carlo N-Particle), created in the laboratory of Los Alamos (United States) was used for the simulation to calculate reactors and the interaction of neutrons, photons and electrons with matter. With this program, it has been calculated reflection coefficient, transmission and absorption of neutrons substance and the reaction rate as a function of neutron energy. Obtained results were compared with the results of analytical calculations. Also, the analysis was made to select the geometry catalyst composition, in which reaction efficiency cyclic be maximized. The calculation of the concentration of the catalytic composition of elements was calculated in work.

By varying the neutron energy of 0.02 eV to 10 MeV at a logarithmic scale following results were obtained

• The average number of radiative neutron capture reaction (n, g);

• The average number of elastic collisions of neutrons in the substance;

• The average number of neutrons passing through the plate;

• The rate of alpha particles, depending on the time.

The nature of the passage of neutrons through the material depends on the parameters of irradiating a target spectrum and neutron energies and cross sections of the elements of composition. It is very important role played by the geometric parameters of the target and the spectrum of the neutron flux. With MCNP program, we can calculate the passage of neutrons through the composition depending on the neutron energy and the thickness of the plates and determine the most suitable geometry for irradiation.

The main result of this simulation is to calculate the reaction rate (n, α), i.e. the rate of formation of alpha particles. Since the catalytic conversion of a part must be four neutrons in the alpha particle, the speed of this reaction should not change over time. Thus it is possible to check the correctness of the theoretical results of the catalytic composition, calculated in. The main sources of alpha particles and are Po211 Po210 core. Po211 allocates α-particle in the reaction Po211 (n, α) Pb207. With MCNP program can calculate the speed (n, α) reactions to this. The results are shown in Figure 4.g. The most minimum time interval is equal to 10-8 c (1-shake) and the exposure time equal to 104 seconds or 1012 shakes (2.777 hour).The rate of reaction (n, a) become stable after exposure time of 10-3 seconds and the number of produced helium nuclei does not change in time. These simulation results are proof that the initial condition concentrations were correct.

Proof of the existence of the neutron catalysis is s-process occurring inside stars. It is believed that the s-process is one of the main processes of nuclear fusion in the massive main sequence stars. But to create a model to meet the flow conditions of the s-process in the land impossible. But you can choose the elements for the flow of cyclical reactions and initial concentration of these elements so as to perform cyclic nuclear reaction.

Multidimensional Gravity and Cosmology, Variations of Constants and New SI

Vitaly Melnikov

Centre for Gravitation and Fundamental Metrology, VNIIMS, and Institute of Gravitation and Cosmology, PFUR, 46 Ozernaya Str., 119361, Moscow, Russia

New challenges to theoretical physics and the role of gravity and cosmology are discussed.

Problems of gravitation as the fundamental interaction and fundamental physical constants choice, their classification, number, precision of measurement, possible variations and their role in fundamental theories of physics are analyzed.

Suggestions for transition to new definitions of SI units based on fundamental constants, different variants and arising problems are analyzed.

Special attention is devoted to theories with variations of constants, especially with scalar fields and multidimensional ones and the problems of G: its absolute value measurements, possible time and range variation.

The dynamics of electron-hole plasma in the semiconductor excited by high power light pulses

Serik Kumekov

Institute of High Technologies and Sustainable Development at the K.I. Satpayev Kazakh National Technical Research University Almaty, 050013, Republic of Kazakhstan; E-mail: skumekov@mail.ru

Interband absorption of a short light pulse causes the reversible transparency of a GaAs sample on a picosecond time scale. Right after the pulse, on a time span shorter than that of the spontaneous recombination, the condition of the developed electron-hole plasma depends neither on the pulse energy, nor on the energy of exciting photons. The radiation has been found that correlates with the excitation on a picosecond time scale. The mechanisms of reversible transparency and superluminescence have been studied. Cooling time of the electron-hole plasma in semiconductor increases considerably with the plasma

concentration. The reason for such a slowing down of cooling is shown to be the heating of optical phonons. An estimate for the time needed to restore quasi Fermi distribution among the nonequilibrium electrons is obtained. The conditions are found for the emergence of relaxation oscillations of superluminescence resulting from the recovery of equilibrium distribution.

To the theory of electrostatic probe in dusty plasma, generated by a volume source of fission fragments

S.Kunakov , Zh.Bolatov, A.Shapiyeva
International IT University, Almaty, Kazakhstan; ***e–mail:*** sandybeck.kunakov@gmail.com

In the present paper the theory of electrostatic probe in nuclear induced dusty plasma is regarded .The grains are equally small in their mass and size .The charging process in plasma is limited by interaction of dust grains and electrons by quasi neutrality condition and total gain's charge is equal to $Z=\frac{3kT_e r_0}{2e^2}$ and reaches its maximum values up to $10^4 e$[1].We define the ratio of electrons concentration and positive ions concentration in the undisturbed region by probe field as $d=\frac{n_e}{n_+}$,which also should be obtained. The nuclear induced plasma in core of nuclear reactor is created by the following nuclear reaction $^3He+n\rightarrow p+T+0.76Mev$. In present paper the theoretical analysis developed to get the detailed explanations of probe diagnostics technique of negative grains in plasma mixtures like $^3He+DG(grains)$,where electrons and negative grains are presented in unknown proportion.

Application of sum coincidence corrections for study of reaction rate of residual nuclei in fission and spallation

Fariza Sagimbaeva
Joint institute for nuclear research, Dubna, Russia; E-mail.ru: fariza-dutches@mail.ru

Nowadays, problem with managing of spent nuclear fuel is an important issue. Therefore development of advanced nuclear systems is essential. Our group in the Joint Institute for Nuclear Research focuses on accelerator driven systems. It uses special set-ups made from spallation target and subcritical blanket. The set-ups are irradiated by relativistic proton or deuteron beam and a vast amount of neutrons comes into existence. Use of activation detectors for measurement of the neutron production is a reliable and very convenient method. When reaction rates of residual nuclei from fission and spallation reactions are evaluated, corrections of sum coincidence effect need to be taken into consideration.

Analyzing power of Inverse Diproton Photodisintegration at Intermediate Energies

Bota Baimurzinova
baymurzinova@jinr.ru (JINR, Dubna)

The reaction $\gamma + \{pp\}_s \rightarrow p + p$, where diproton $\{pp\}_s$ is a proton pair in $^1S_0$ state, is a spin-isospin partner of the fundamental reaction of deuteron photodisintegration. The inverse reaction, the hard bremsstrahlung $p + p \rightarrow \gamma + \{pp\}_s$, has been observed with the ANKE spectometer at COSY-Julich. It's analyzing power has been measured at forward angles at several energies in the region of (1232) isobar exictation. Together with the di erential cross section measured earlier, it would allow to better estimate various multipoles contributions.

Multipole structure of compact objects

Hernando Quevedo
National Autonomous University of Mexico and University of Rome

From a theoretical point of view, to completely describe the gravitational field of compact objects it is enough to know their multipole structure. In Einstein theory, however, it is very difficult to find physically meaningful exact solutions with a given multipole structure. In this talk, I will review the main attempts utilized so far to attack this problem, and will propose a novel method which takes into account the mathematical symmetries of the field equations.

Observational and theoretical constraints on the mass-radius relations of neutron stars

Kuantay Boshkayev
Physical–Technical Faculty, Al-Farabi Kazakh National University, Al-Farabi ave. 71, 050040 Almaty, Kazakhstan

The equilibrium configurations of slowly rotating neutron stars are investigated by using the Hartle formalism in the case of the Einstein-Maxwell-Thomas-Fermi equations [1]. We integrate these equations of equilibrium for different central densities and angular velocities and compute all basic parameters describing physical properties of neutron stars. Both the Keplerian mass-shedding limit and the axisymmetric secular instability are used to construct the new mass-radius relations. We show the mass-radius relations together with the most recent and stringent constraints indicated by Trumper [2].

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Dynamics of two-cluster systems in phase space

Yuliya Lashko[1], Gennady Filippov[1], and Viktor Vasilevsky[1]
[1]*Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine*

We present a phase-space representation of quantum state vectors for two-cluster systems which is valid both for finite h^1 and when h^1 goes to zero. The Bargmann-Segal transformation was used to map wave functions of two-cluster systems in the coordinate space into the Fock-Bargmann space. The density distribution in the phase space was compared with those in the coordinate and momentum representations.

Density distributions in the Fock–Bargmann space were constructed for bound and resonance states of $^{6;7}$Li and $^{7;8}$Be, provided that all these nuclei are treated within a microscopic two-cluster model. The dominant two-cluster partition of each nucleus was taken into consideration: ^6Li = ® + d, ^7Li = ® + t, ^7Be = ® +^{3} He, ^8Be = ® + ®. The microscopic model is based on the resonating-group method and uses a full set of oscillator functions to expand a wave function of relative motion of interacting clusters. The input parameters of the model and nucleon-nucleon potential were selected to optimize description of the internal structure of clusters and to reproduce position of the ground state with respect to the two-cluster threshold.

We considered a wide range of excitation energies of compound systems, but special attention was devoted to the bound and resonance states. Bound states and narrow resonance states realize themselves in a very compact area of the phase space. We establish the quantitative boundaries of this region for the nuclei under consideration. Phase portraits of the high-energy excited states peak along the line which coincides with a classical trajectory.

Lightest Kaonic Nuclear Clusters

Roman Ya. Kezerashvili[1,2], Shalva M. Tsiklauri[3], N. Takibayev[4]
[1)]Physics Department, The City University of New York, Brooklyn, NY 11201, USA; [2)] The Graduate School and University Center, New York, NY 10016, USA; [3)] Borough of Manhattan Community College, New York, NY 10007, USA; [4)] Al-Farabi Kazakh National University, 480078, Almaty, Kazakhstan

We present our study of kaonic three-body KNN, KKN and KKK and four-body KNNN, and KKNN clusters within the framework of a potential model using the method of hyperspherical functions in momentum representation. To perform a numerical calculations for the bound state energy of the light kaonic system, we use a set of different potentials for the nucleon-nucleon and KN interactions, as well as for the kaon-kaon interaction. The calculations show that a quasibound state energy is not sensitive to the NN interaction, and it shows very strong dependence on the KN potential. We also compare our results with those obtained using different theoretical approaches. The theoretical discrepancies in the binding energy and width for the lightest kaonic system related to the different NN and KN interactions are addressed.

Phantom compact and extended objects in astrophysics

V.Dzhunushaliev, A.Makhmudov, A.Urasalina
Al-Farabi Kazakh National University

We investigate localized and extended objects for gravitating, self-interacting phantom fields. This study covers phantom boson stars, phantom cosmic strings, phantom domain walls and phantom traversable wormholes. These four systems are solved numerically and we try to draw out general, interesting features in each case. In each of the four systems we find regions of the parameters where there is a balancing between the tendency of gravity to collapse the system and the tendency of the phantom fields to disperse the system.

Fractal - geometric description of the "distance - speed" chart for antigravitating galaxies

Z.ZH. Zhanabaev, S.A. Khokhlov, A.T. Agishev*
Al-Farabi Kazakh National University, Kazakhstan, Almaty;
**E-mail:* aldiyar.agishev@gmail.com

Current astrophysical observations demonstrate expansion of the universe. It can be considered as anti-gravity effect, which is observed as "Scatter" of galaxies from each other with increasing acceleration. This effect has been described in detail in a number of papers, such as [1,2]. Physical nature of antigravity is intensively studied by using the concept of "dark energy." On the other hand the cosmological laws have long studied with fractal theory [3].

The fractal theory suggests an independent choice of minimal measurement scale of measures on values of the determined measures. Geometric measures in theory of gravity must depend on spatial distribution of matter and relevant minimum geometric scale. For this purpose, we can choose a typical distance R_* and use the nonlinear equation of fractal measures [4].

$$X_{i+1} = R\left(\left|1 - \frac{R_*}{X_i}\right|\right)^{-\gamma} \qquad (1)$$

where R_* is radius of zero gravity, γ is the difference between topological and fractal dimensions of matter distribution, R is distance from the observer, X is the minimum deviation from R.

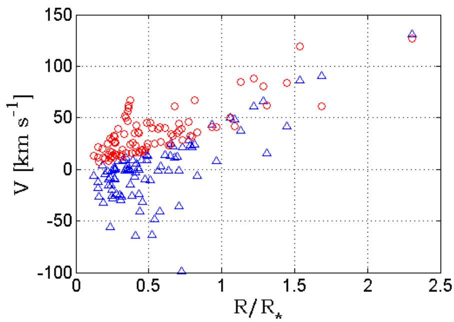

Figure 1 – Diagram "distance - speed" for the local group, γ = 0.194, R_* = 0.89 Mpc.

Positive speed values can be found from (1) as $V_{i+1} = {dX_{i+1}}/{dR} = {dX_{i+1}/dt}/{dR/dt}$ and negative values from the Kramers – Kronig relations as

$$\frac{dX''(R)}{dR} = -\frac{1}{\pi}\frac{X'(R)}{R_*-R} \qquad (2)$$

where $X'(R)$ is real part of $X(R)$ and $X''(R)$ is imaginary part of $X(R)$. Absolute values of the velocities as [km s^{-1}] we can find via the Hubble constant: V = Vi * Hx * R, where Hx = 72 [km s^{-1} Mpc^{-1}] (Fig.1.)

The present theory can be considered as a scale – invariant approach. So, via this theory, we have obtained the same results correctly describing observations of another clusters.

In this paper we propose a new idea for the description the behavior of a physical quantity near its critical value in the form of non-linear fractal measures. As a critical distance from the viewpoint we have adopted sizes of the galaxies groups and distance from the zero gravity barycenter's. This approach to the problems of cosmology is different from other modern research that it`s the simplest way for realization of the basic idea of the general theory of relativity, which is the relationship of space structure with distribution of matter.

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Calculation of neutron resonances parameters of scattering by system of two heavy nuclei

V.O.Kurmangalieva, D.M.Nasirova, N. Zh.Takibayev
Al-Farabi Kazakh National University
**Abai Kazakh National Pedagogical University*

Neutron scattering processes in two heavy nuclei system belong to the class of quantum-mechanical problems, which are becoming more and more interesting. This interest is connected not only with explanation of nuclear interactions details, but also a manifestation of extraordinary events, the inherent problems of three or more bodies. The examples of this are Thomas [1] and Efimov [2] effects, which describe the "fall of particles to the center" and "increase in the number of bound states" in the three-particle systems. New developments in three-particle systems have been identified, concerning "movement of Efimov levels to threshold or from threshold" when you change interaction forces, while the main ("not Efimov") levels are moving in the opposite direction [3]. This phenomenon has been used in experiments to identify the Efimov levels [4]. These effects are amazing and unusual features of quantum problem of three (and more) interacting bodies, which have been confirmed in a number of unique and subtle experiments [4].

Two-particle processes of neutron scattering on a system of two heavy nuclei were considered in this paper. The resonance amplification mechanism of interaction between the heavy nuclei was investigated. The problem of neutrons scattering at crystal structures, in which nuclei are fixed in the crystal lattice was also considered. The use of crystal lattice allows get nucleus "heavier" as well as in Messbauera effect. Two-body interaction of neutron with nucleus was taken in the Breit-Wigner form, which allows the use of analytical expressions for two-enforcement amplitudes of neutron scattering at the nucleus. Calculations have shown that two-particle amplitudes have a resonant dependence not only on energy but also on the distance between the nuclei lattice.Calculations of three-particle type resonances were conducted for ^{103}Ag, ^{52}Cr, ^{51}V, ^{157}Gd and other nuclei.

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Phonon-nuclear interactions in the crystalline structures of neutron stars and white dwarfs

Zh. Omar, N. Takibayev, V. Kurmangalieva
al-Farabi Kazakh National University; jadyra-07@mail.ru

Visible compact stars such as white dwarfs and neutron stars, are of great interest to researchers due to an extremely high density and unusual reactions and processes that take place in the stellar matter. Usually assume that the matter in the center of white dwarf has a crystalline structure formed with bare nuclei, which loaded into electron Fermi-liquid [1]. The neutron stars have more huge density therefore the crystalline structures are formed already at envelopes of these stars. We investigated the interactions that can happen in the crystalline structures, particularly between phonons in the crystal and Fermi-electrons and nuclei [2].

It is remarkable that photons can create a group of electron-hole pairs near Fermi energy surface and lead to the excitation of nuclei. In this case, the nonlinear interactions become very important. Our estimations and calculations demonstrated the dependence of the velocity of processes from the element composition of stellar matter.

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Reactions of Li and Be isotopes with neutrons

Duisenbay A.D., Takibayev N.Zh., Kurmangalyeva V.O.
Faculty of Physics and Technology, Al-Farabi Kazakh National University, Al-Farabi ave. 71, 050040 Almaty, Kazakhstan

All light nuclei have several isotopes. They are stable and radioactive. The isotopes have their own properties and characteristics.

Lithium is an alkaline metal. Nowadays lithium has nine isotopes and two excited isomer states of ^{10m1}Li – ^{10m2}Li nuclides. There are two stable isotopes - ^{6}Li and ^{7}Li. ^{6}Li is used in thermonuclear energetics. The capture section (σ) of thermal neutrons by lithium isotopes is different: ^{6}Li 945 barn, ^{7}Li 0,033 barn [1]. The use of lithium in technics is important.

Neutrons induce some nuclear reactions which are important in divisions of high nuclei, also in formation of radioactive isotopes. The main property of such reactions with neutrons is a growth by parabolic law of reaction section while the energy of neutrons decreases. Thus, many ordinary nuclear reactors operate with neutrons which are in a thermal equilibrium with environment [2]. Neutrons participate in all interactions of elementary particles. They are strong, electromagnetic, weak and gravitational [3].

Reactions of Li and Be isotopes with neutrons in nuclear reactors were studied theoretically and reactions energies were calculated. The reactions, which has sufficient energies can be in nuclear reactors. For instance,

$$ {}^{6}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n} \rightarrow \begin{cases} {}^{3}_{1}\mathrm{H} + {}^{4}_{2}\mathrm{He} + 4{,}782\ \mathrm{MeV} \\ {}^{7}_{3}\mathrm{Li} + \gamma + 7{,}249\ \mathrm{MeV} \end{cases} $$

The passage of such reactions and sufficient energies are very important in nuclear energetic, because almost all reactions in nuclear reactors are important in energy production.

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The erez-rosen solution versus the hartle-thorne solution

Sh.S.Suleimanova, K.A.Boshkayev, B.Zhami, Zh.A.Kalymova

Faculty of Physics and Technology, Al-Farabi Kazakh National University, Almaty

An exact solution that describes exterior field of a static object with the quadrupole moment has been obtained by Erez and Rosen (ER) in 1959 using Weyl method [1]. The ER solution reduces to the Schwarzschild solution for vanishing quadrupole parameter $q \to 0$. The properties of gravitational field in ER spacetime have been investigated in Ref. [2]. As a result, it shows new characteristics complementing effects observed for the Schwarzschild spacetime [3, 4].

On the other hand, there exists an approximate solution for slowly rotating, slightly deformed objects so-called Hartle-Thorne (HT) solution [5]. Unlike most of the exact solutions the approximate HT solution possesses its internal counterpart, which makes it practical in astrophysical context. The solution has been determined up to the second order terms of the body's angular velocity i.e. its accuracy is valid up to the first order terms in the quadrupole moment Q and second order in the angular momentum *J*.

The main purpose of this work is to show the relationship between the ER and the HT solutions for the vanishing angular momentum *J*=0. Indeed, the first attempt in this direction has been made in Ref. [3], where the ER solution has been subjected to the Zipoy-Voorhees transformations $j = 1 + \sigma q$, where j is the Zipoy-Voorhees parameter and σ is a real number. Since the ER is the exact solution it has been expanded up to the first order terms in the quadrupole parameter. Afterwards, by setting $\sigma = -1$ the coordinate transformations from the ER to HT solutions have been obtained with algebraic relations $M_{HT} = M_{ER}(1 - q)$, $Q = \frac{4}{5}M^3 q$, where M is the mass of the central object.

However in this work we found these relations without setting $\sigma = -1$. Instead, we directly calculated its value from the metric functions by means of method of undetermined coefficients. Thus, our results are fully in agreement with the well-known ones and can be considered as an alternative approach.

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Application of geometrothermodynamics in the investigation of the ideal gas

M. Abishev[1], A. Malybayev[1], H. Quevedo[2]
[1]Physical-Technical Faculty, Al-Farabi Kazakh National University, Al Farabi av. 71, 050040 Almaty, Kazakhstan
[2]Institute of Nuclear Sciences, National Autonomous University of Mexico, AP 70543, Mexico, DF 04510, Mexico

In this work, we investigate the geometric properties of the equilibrium space of the ideal gas. We show that the thermodynamic properties of the ideal gas can be investigated by using the formalism of geometrothermodynamics (GTD) which establishes a connection between the geometric properties of the equilibrium space of a thermodynamic system and its physical properties.

In GTD, the thermodynamic variables are used as coordinates for the thermodynamic phase space $\mathcal{T}$, which in this case is 5-dimensional with coordinates $(\mathrm{S}, \mathrm{U}, \mathrm{V}, \mathrm{T}, \mathrm{P})$. In addition, the equilibrium space $\mathcal{E}$ is a 2-dimensional subspace of $\mathcal{T}$. Then, we introduce the so-called fundamental Gibbs 1-form Θ. Moreover, we introduce a metric G in the thermodynamic phase space $\mathcal{T}$, which depends on all the coordinates of $\mathcal{T}$, i.e. $\mathrm{G} = \mathrm{G}(\mathrm{S}, \mathrm{U}, \mathrm{V}, \mathrm{T}, \mathrm{P})$, where S is the entropy, U the internal energy, V the volume, T the temperature and P is the pressure.

The fundamental Gibbs 1-form Θ and the metric G are invariant with respect to Legendre transformations. For the equilibrium subspace $\mathcal{E}$ we choose the variables U and V as coordinates. Then, we can specify a fundamental equation as $S = \mathrm{S}(\mathrm{U}, \mathrm{V})$. The projection of the metric G on $\mathcal{E}$ induces a metric g on $\mathcal{E}$. The metric of the equilibrium space of a thermodynamic system with two degrees of freedom (U, V) can be written as:

$$\mathrm{g_S} = \left(\mathrm{U}\frac{\partial \mathrm{S}}{\partial \mathrm{U}}\right)^{2\mathrm{k}+1} \frac{\partial^2 \mathrm{S}}{\partial \mathrm{U}^2}\mathrm{dU}^2 + \left(\mathrm{V}\frac{\partial \mathrm{S}}{\partial \mathrm{V}}\right)^{2\mathrm{k}+1} \frac{\partial^2 \mathrm{S}}{\partial \mathrm{V}^2}\mathrm{dV}^2 + \left[\left(\mathrm{U}\frac{\partial \mathrm{S}}{\partial \mathrm{U}}\right)^{2\mathrm{k}+1} + \left(\mathrm{V}\frac{\partial \mathrm{S}}{\partial \mathrm{V}}\right)^{2\mathrm{k}+1}\right] \frac{\partial^2 \mathrm{S}}{\partial \mathrm{U}\,\partial \mathrm{V}}\mathrm{dUdV} \tag{1}$$

In the case of an ideal gas, the fundamental equation in the entropy representation can be expressed as:

$$S(U, V) = S_0 + Nk_B c_V \ln\left(\frac{U}{U_0}\right) + Nk_B \ln\left(\frac{V}{V_0}\right) \tag{2}$$

By substituting (2) into (1) we obtain the simple metric:

$$g_S = -(Nk_B)^{2k+2}\left[c_V^{2k+2}\left(\frac{\partial U^2}{U^2}\right) + \left(\frac{\partial V^2}{V^2}\right)\right]$$

The curvature of this metric is identically zero. We interpret the absence of curvature as the absence of thermodynamic interaction. One of the goals of GTD is to interpret the curvature of the space of equilibrium states as a measure of thermodynamic interaction. This goal has been reached here in the case of the ideal gas.

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