



***Bogoliubov Laboratory of
Theoretical Physics***

THEORETICAL PHYSICS AT BLTP

V. V. Voronov

*BRAZIL-JINR FORUM
Dubna, June 15-19, 2015*



Laboratory of Theoretical Physics, JINR



May 25, 1956

П Р И К А З

ПО ЛИЧНОМУ СОСТАВУ ОБЪЕДИНЕННОГО ИНСТИТУТА

№ 5

"25" мая 1956 года.

До утверждения новой структуры Института возложить на академика БОГОЛДЬБОВА Николая Николаевича /начальника сектора № 3 Теоретической лаборатории/ исполнение обязанностей директора Теоретической лаборатории Объединенного Института.

ДИРЕКТОР

ОБЪЕДИНЕННОГО ИНСТИТУТА ЯДЕРНЫХ ИССЛЕДОВАНИЙ

Д.И. БЛОХИНЦЕВ

ПО ЛИЧНОМУ СОСТАВУ ОБЪЕДИНЕННОГО ИНСТИТУТА

№ 6

"25" мая 1956 г.

- ЗАЧИСЛИТЬ: 1. БОГОЛДЬБОВА Николая Николаевича временно начальником сектора № 3 Теоретической лаборатории с окладом 6000 руб. в месяц, с 1 июня с.г.
2. ШИРКОВА Дмитрия Васильевича старшим научным сотрудником сектора № 3 Теоретической лаборатории с окладом 1500 руб. в месяц по совместительству, с 1 июня с.г.
3. МЕДВЕДЕВА Бориса Валентиновича старшим научным сотрудником сектора № 3 Теоретической лаборатории с окладом 1500 руб. в месяц по совместительству, с 1 июня с.г.
4. ПОМИЯНОВА Михаила Константиновича научным сотрудником сектора № 3 Теоретической лаборатории с окладом 1000 руб. в месяц по совместительству, с 1 июня с.г.

ДИРЕКТОР

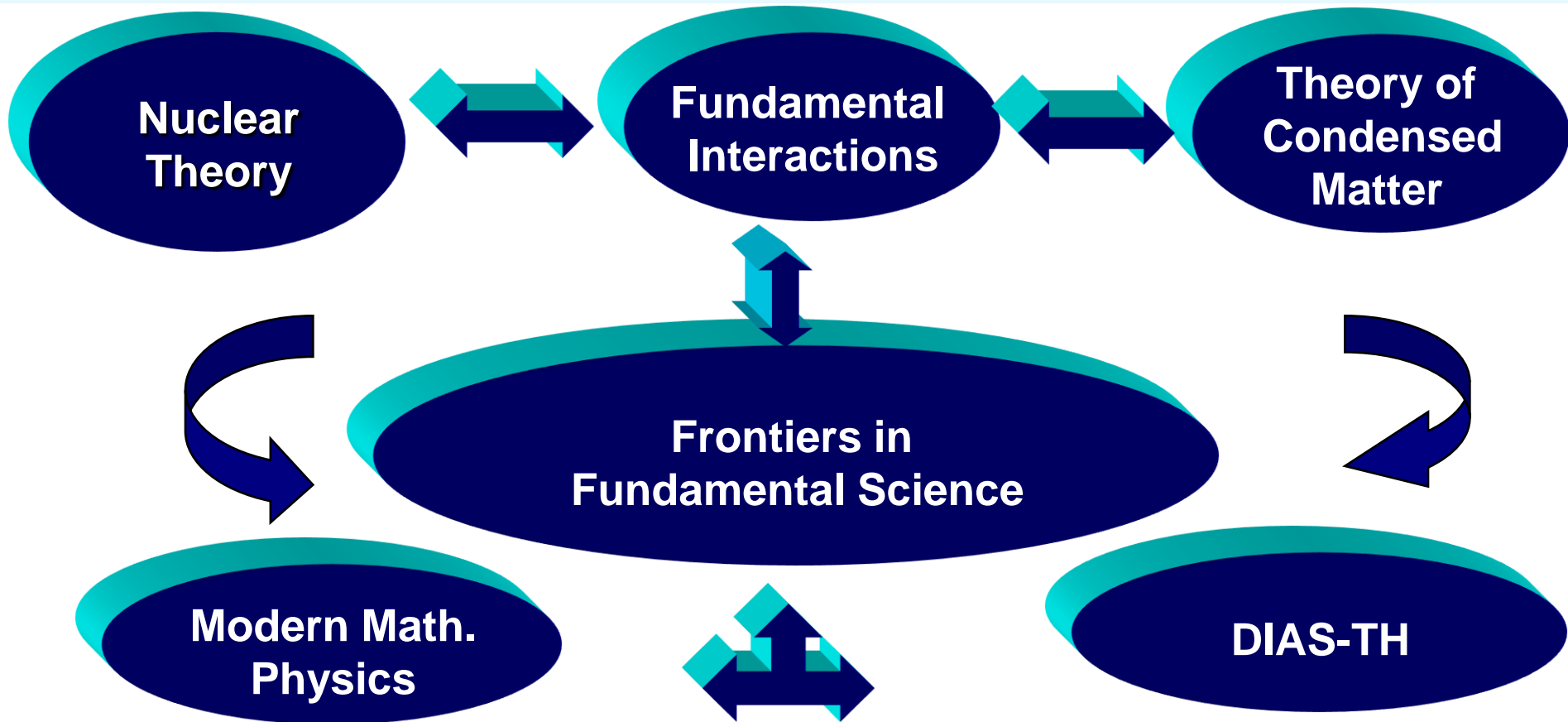
ОБЪЕДИНЕННОГО ИНСТИТУТА ЯДЕРНЫХ ИССЛЕДОВАНИЙ

Д.И. БЛОХИНЦЕВ



BLTP's Scientific Policy

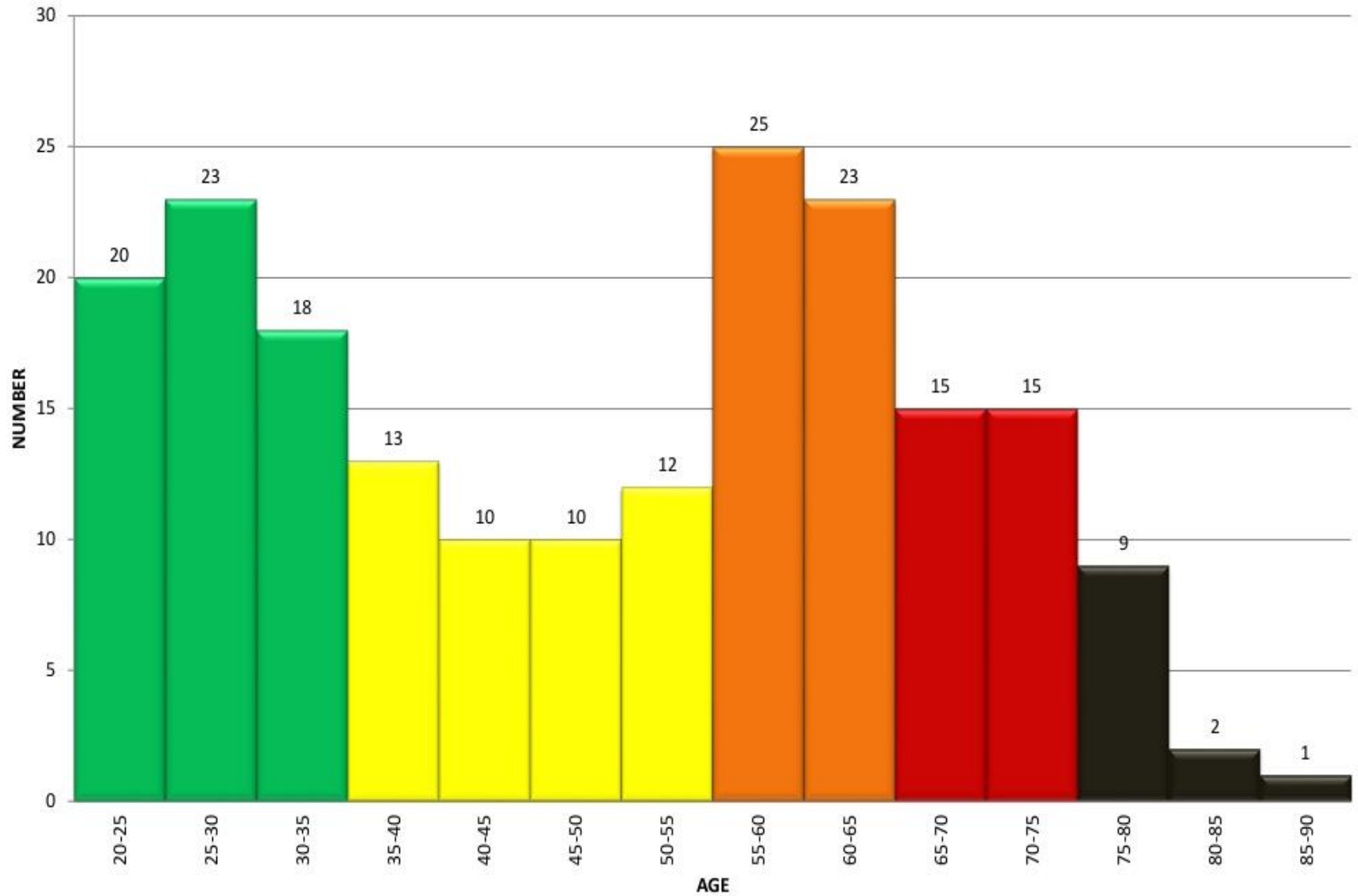
Development of research in **Theoretical Physics**
on the basis of **Advanced Mathematics**;
Multidisciplinary research;
Support of the **JINR Experimental Programme**;
Strengthening of the **efficiency of scientific staff** through
the interplay of **Research and Education**.



Scientific Personnel

	D	C	O	Total
Fundamental Interactions	30	27	26	83
Nuclear Physics	25	23	20	68
Condensed Matter	16	22	10	48
Mathematical Physics	13	12	7	32
Total	84	84	63	231

BLTP scientific personnel



SCIENTIFIC PERSONNEL BY COUNTRY (BLTP)

Country	Total	Country	Total
Russia	165	Germany	6
Czech Republic	5	Poland	3
Mongolia	1	Bulgaria	7
Turkey	1	Korea	1
Belarus	2	India	3
Kazakhstan	9	Uzbekistan	3
Slovakia	7	Moldavia	1
Azerbaijan	2	Mexico	1
Ukraine	3	Romania	3
Tajikistan	1	Japan	1
Vietnam	1	Argentina	1
Armenia	4		
Total - 231 (165 scientists from Russia and 66 from other countries)			

2014-2018: Themes and projects

Theory of Elementary Particles and Fields

Projects:

- Standard Model and Its Extension,
- QCD Parton Distributions for Modern and Future Colliders,
- Physics of Heavy and Exotic Hadrons,
- Mixed Phase in Heavy-Ion Collisions.

Nuclear Theory, Nuclear Structure and Dynamics

Projects:

- Nuclear Structure far from Stability Valley
- Nucleus-Nucleus Collisions and Nuclear Properties
- Exotic Few-Body Systems,
- Nuclear Structure and Dynamics at the Relativistic Energies.

Theory of Condensed Matter and New Materials

Projects:

- Physical properties of complex materials and nanostructures
- Mathematical problems of many-particle systems

Modern Mathematical Physics

Projects:

- Quantum groups and integrable systems
- Supersymmetry
- Quantum gravity, cosmology and strings

Research and Education Project “Dubna International School of Theoretical Physics (DIAS-TH)”

Bogoliubov Laboratory of Theoretical Physics

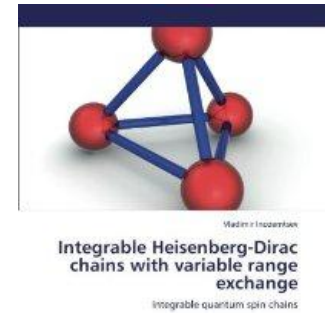
Publications, 2014

Journals & Conf. Proc ~ 490



Conferences and Schools

Total - 16 (~ 1000 participants)
DIAS-TH and Helmholtz Schools - 4
> 20 countries were represented



Educational Activity

More than 40 lecture courses at JINR UC, DIAS-TH, Moscow U., Dubna U., MPTI, etc.



Awards, Grants and Fellowships

Outstanding APS Referee Award – V.S. Melezhik

Panarmenian Award by World Armenian Congress “Best scientific work” - V. Sargsyan

The Grant of RF President for Young Scientists – A. Bednyakov, A. Pikelner

Fellowship for Young International Scientists of CAS – T. Schneidman

Fellowship FAIR Russia Research Center Young Scientist – I. Egorova

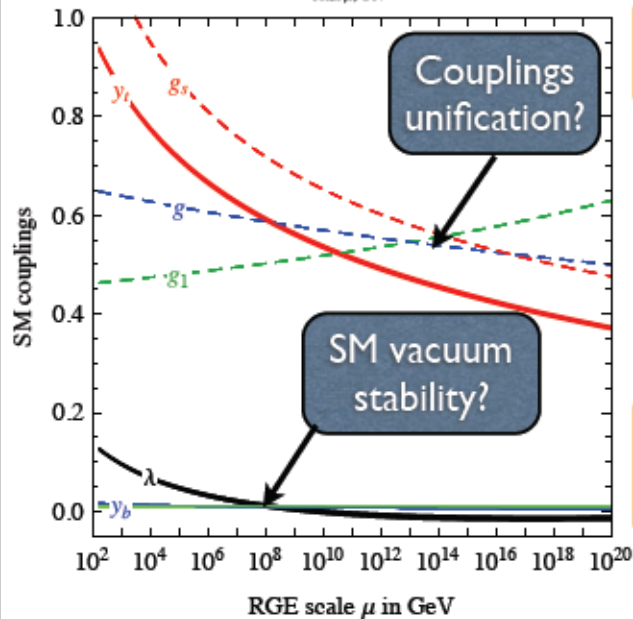
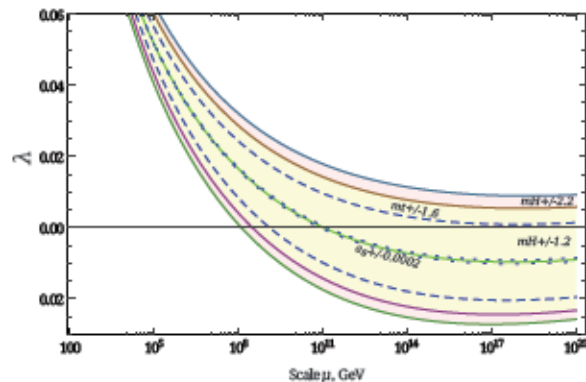
Dozens of grants: RFBR, RFBR-CNSF, RFBR-DFG, RFBR-CNRS, etc.



High precision calculations for LHC

Standard Model Three-loop Beta-Functions Gauge, Yukawa couplings. Higgs self-interaction.

Higgs mass M_h 126 GeV



Gauge couplings unification

Mihaila, Salomon, Steinhauser. *Phys.Rev.Lett.* 108 (2012) 151602

Bednyakov, Pikelner, Velizhanin. *JHEP* 1301 (2013)017

With the current LHC measurement of the SM Higgs boson mass the applicability of the SM can be extended to a very high (e.g. Planck) scale.

Yukawa couplings running

Bednyakov, Pikelner, Velizhanin. *Phys.Lett.* B722 (2013) 336-340

Higgs self-coupling running as a test of SM vacuum stability. Three-loop precision is enough, but more accuracy for input parameters needed.

Higgs self-coupling running

K.G. Chetyrkin, M.F. Zoller. *JHEP* 1304 (2013) 091

Bednyakov, Pikelner, Velizhanin. *Nucl.Phys.* B875 (2013) 552-565

W. de Boer, C. Beskidt (KIT),
D. Kazakov (BLTP JINR)

Phys.Lett. B726 (2013) 758

NMSSM versus MSSM

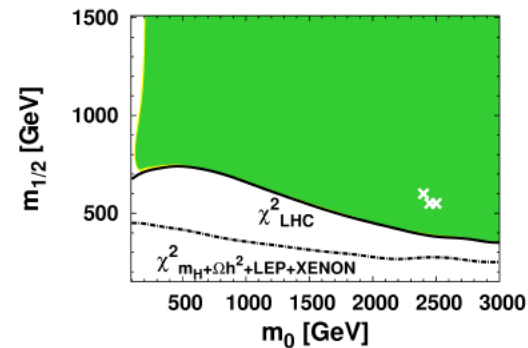
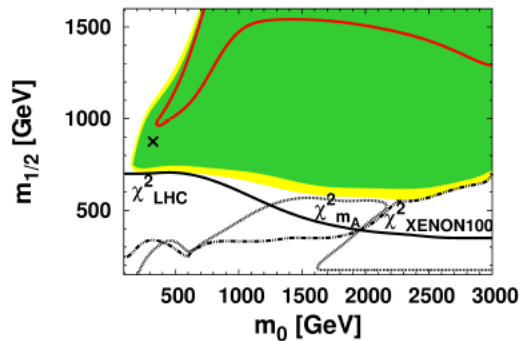
- Allowed regions satisfying all constraints except for the Higgs boson mass are shown in green
- In MSSM 125 GeV Higgs boson mass (red curve) pushes susy masses above 2 TeV (left panel)
- In NMSSM light super partners are allowed (right panel)

Constraint	Data
Ωh^2	0.113 ± 0.004
$b \rightarrow X_s \gamma$	$(3.55 \pm 0.24) \cdot 10^{-4}$
$B_u \rightarrow \tau \nu$	$(1.68 \pm 0.31) \cdot 10^{-4}$
Δa_μ	$(302 \pm 63(\text{exp}) \pm 61(\text{theo})) \cdot 10^{-11}$
$B_s^0 \rightarrow \mu^+ \mu^-$	$B_s^0 \rightarrow \mu^+ \mu^- < 4.5 \cdot 10^{-9}$
m_h	$m_h > 114.4 \text{ GeV}$
m_A	$m_A > 480 \text{ GeV for } \tan \beta \approx 50$
ATLAS	$\sigma_{had}^{SU\text{SY}} < 0.003 - 0.03 \text{ pb}$
CMS	$\sigma_{had}^{SU\text{SY}} < 0.005 - 0.03 \text{ pb}$
XENON100	$\sigma_{\chi N} < 8 \cdot 10^{-45} - 2 \cdot 10^{-44} \text{ cm}^2$

MSSM

Combination of all constraints

NMSSM



NMSSM calculations made with NMSSMTools

U.Ellwanger et al

Field-theoretical approach to neutrino oscillations

The **field-theoretical approach to neutrino oscillations** was developed. It was shown that the higher-order corrections to the large-distance asymptotic behavior of the wave-packet modified neutrino propagator could lead to **the observable effects of breakdown of the classical inverse-square law (ISL) at short but macroscopic distances**. A statistical analysis of available reactor data suggests that the ISL violation could be fully or partially responsible for the reactor anomaly observed in SBL experiments.

V. Naumov, D.S. Shkirmanov, Eur. Phys. J. C 73 (2013)

QCD vacuum structure under extreme conditions: Lattice QCD

Topological gluon configurations and deconfinement transition in QCD

In pure gluodynamics with increasing temperature, topological susceptibility drops sharply down just at the deconfinement transition. In Lattice QCD, the topological susceptibility – Indicator for the transition itself. **The large-scale topological objects play a major role in the change of thermal gauge field ensembles at the deconfinement phase transition in gluodynamics and at the crossover phenomenon in full QCD.**

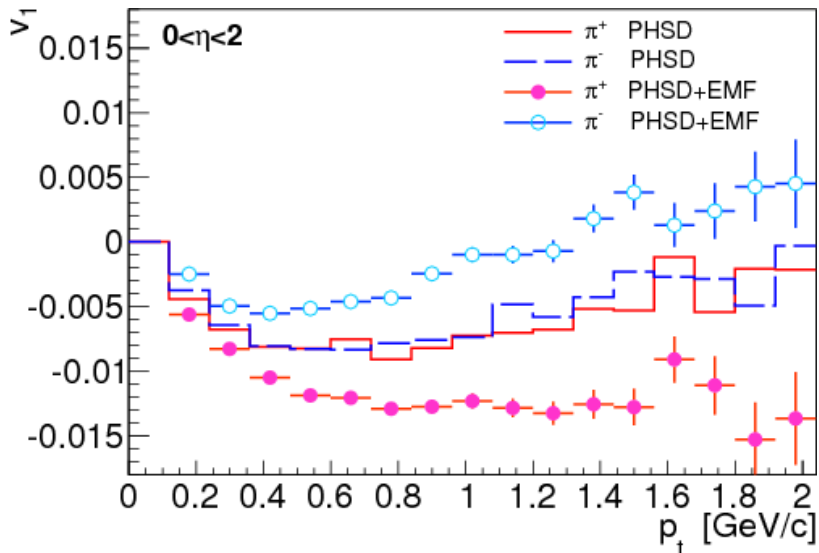
V. Bornyakov, E.-M. Ilgenfritz, B. Martemyanov, V. Mitrjushkin, M. Muller-Preussker, Phys.Rev.D 87 (2013)

Relativistic Heavy Ion Physics:

Charge-dependent directed flow in asymmetric nuclear collisions

The new effect of splitting of the directed flow of identified hadrons with opposite electric charges was predicted for the asymmetric system Cu+Au in non-central collisions at $\sqrt{s_{NN}}=200\text{GeV}$. Due to the difference in the number of protons of the colliding nuclei an electric field emerges which is directed from the heavy to the light nucleus. This strong electric field leads to a splitting of the directed flow for particles with the same mass but opposite electric charges. It is shown that this splitting as a function of the transverse momentum provides a direct access to the electromagnetic response of the very early nonequilibrium phase of relativistic heavy-ion collisions.

V.Voronyuk, V.Toneev, S.Voloshin and W.Cassing, Phys. Rev. C 90 (2014)



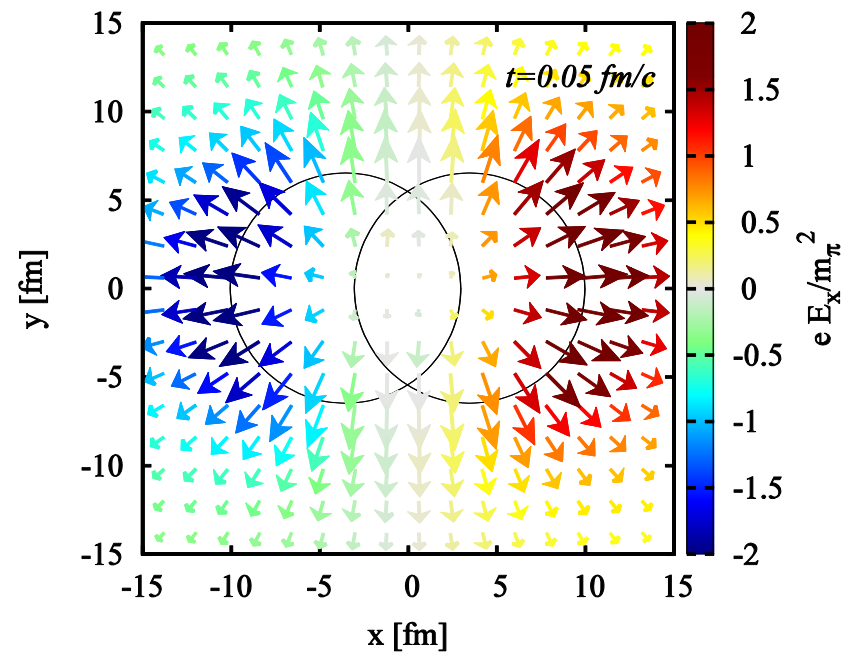
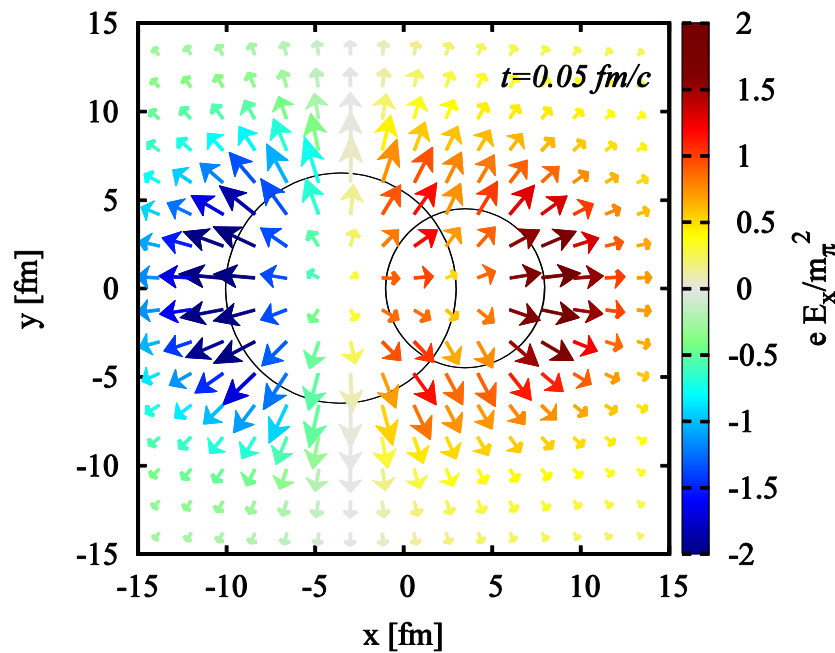
Transverse momentum dependence of the directed flow for pions produced in peripheral Cu+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Filled and empty circles correspond to pions π^+ and π^- respectively.

Electric field in asymmetric collisions

Cu-Au

$\sqrt{s_{NN}} = 200 \text{ GeV}$

Au-Au

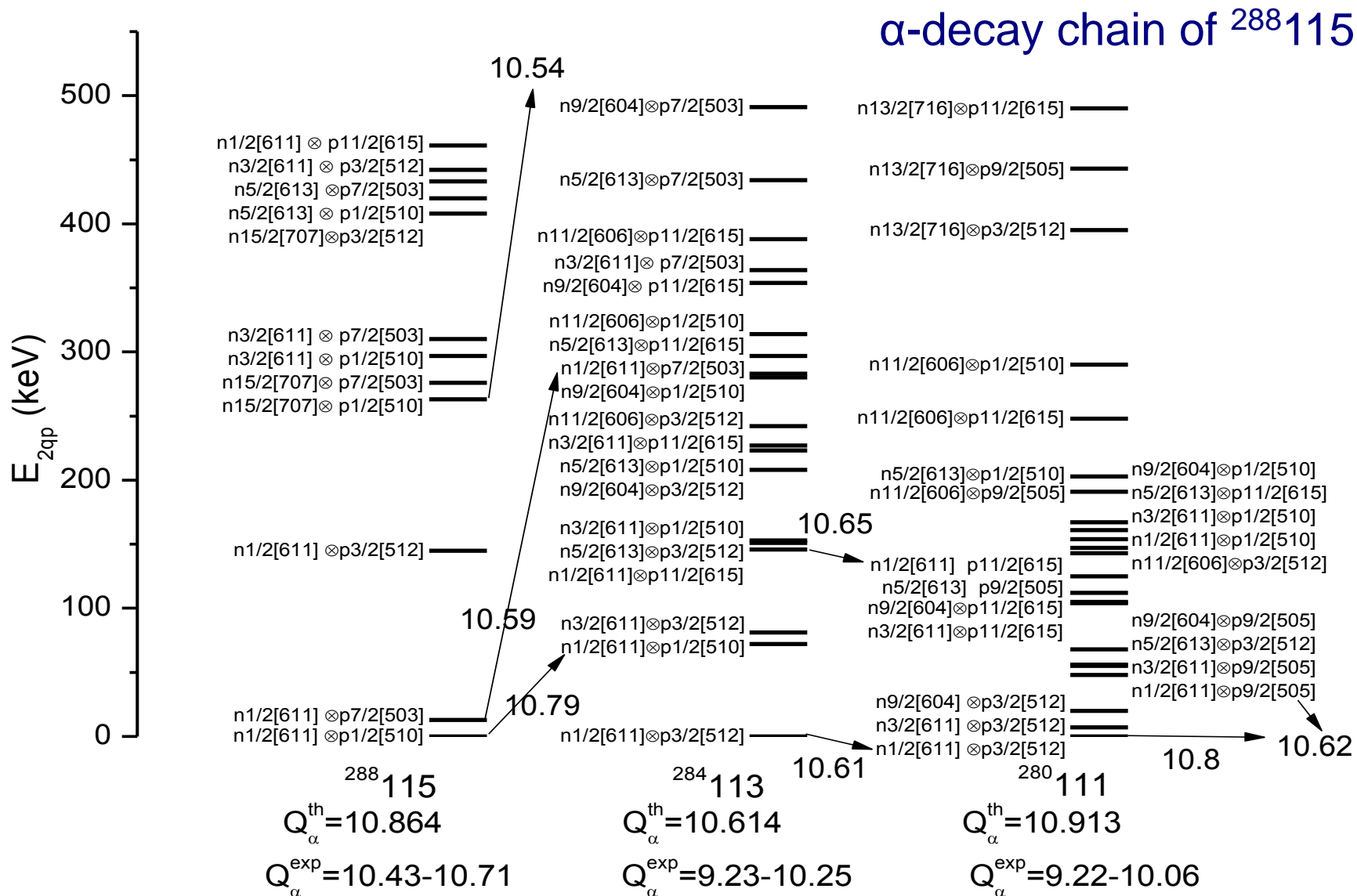


Due to the difference in the number of protons of the colliding nuclei an electric field directed from the heavy to the light nucleus emerges in the nuclear overlapping region

V. D. Toneev et al.

Structure of heaviest nuclei

N.Yu. Shirikova, A.V. Sushkov, R. V. Jolos, V.G.Kartavenko, V.O.Nesterenko, L.A.Malov, G.G.Adamian, N.V.Antonenko, A.N.Bezbakh

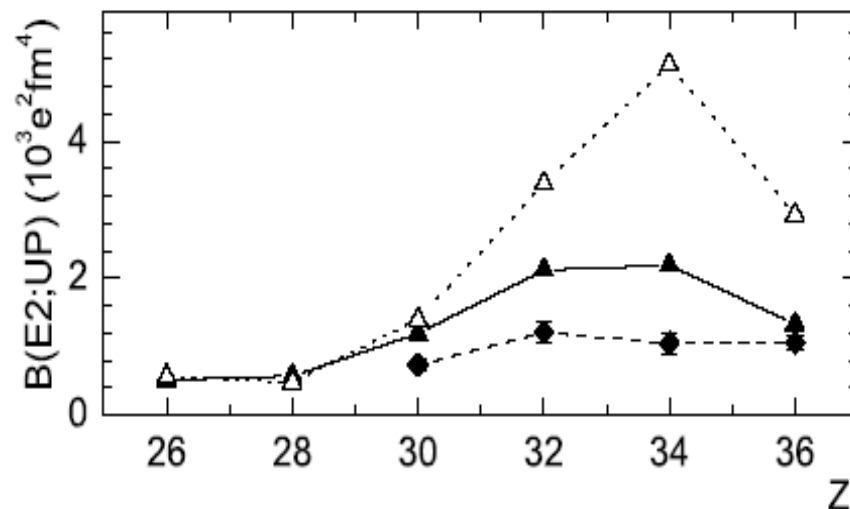
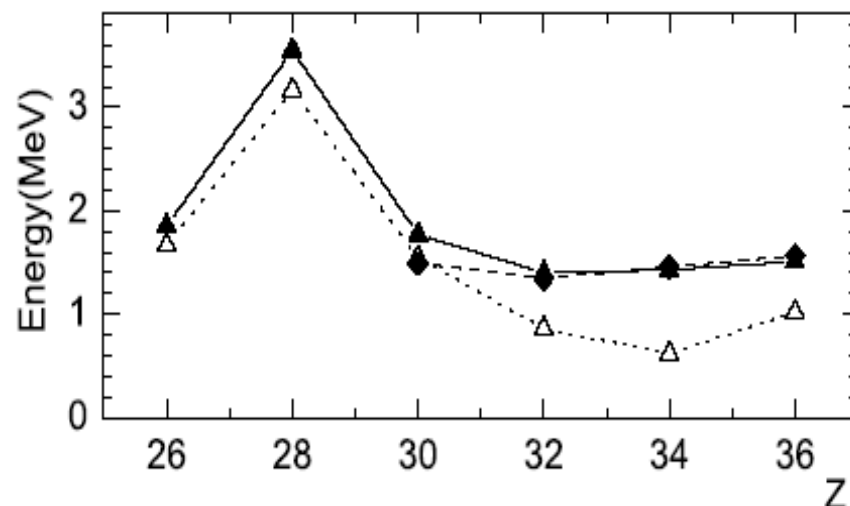


Properties of Nuclei at the Border of Stability

The development of modern microscopic methods to predict and describe spin- and isospin properties of exotic nuclei.

A.P. Severyukhin, V.V. Voronov,
I.N. Borzov, N.N. Arsenyev et al.

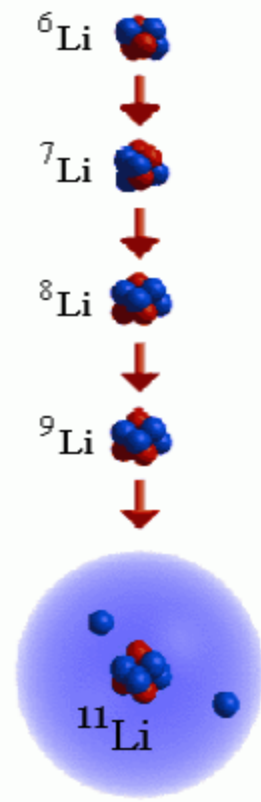
Energies and $B(E2)$ values for up transitions to the 2^+_{1} QRPA states in the neutron-rich $N = 50$ isotones. Results of the calculations without the tensor interaction (open triangles) and with the tensor interaction (filled triangles) are shown. Experimental data (filled diamonds) are shown.



Halo Nuclei

S. N. Ershov et al

Cluster degrees of freedom are manifested in weakly bound systems
Nature of such systems is studied within the few-body cluster theory



***Explorations of nuclear structure and nuclear reactions
at limits of stability and beyond***

Tools and topics

***coupled-channel description within few-body cluster
models***

***combined studies of reaction mechanisms and nuclear
structure in various low-energy processes***

***correlation studies of few fragments
continuum spectroscopy of radioactive nuclei***

two-proton emitters in a three-body models

resonance structures beyond driplines

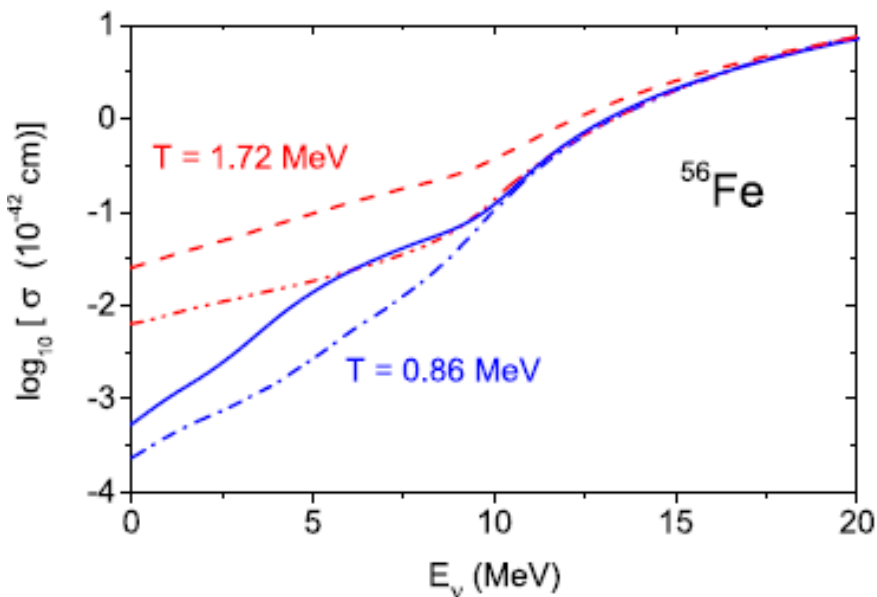
reactions with halo nuclei

Inelastic neutrino scattering off hot nuclei in supernova environments

Alan A. Dzhioev, A.I. Vdovin, J. Wambach, V. Yu. Ponomarev

Phys. Rev. 89 (2014) 035805

Inelastic neutrino scattering off hot nuclei for temperatures relevant under supernova conditions was studied. Thermodynamically consistent method based on the thermo field dynamics was used. It is shown that the main contribution to inelastic ν -A scattering at $E_\nu < 10$ MeV is due to the de-excitation processes of hot nuclei. The de-excitation is responsible also for the emission of pairs from hot nuclei. At the energies $E_\nu < 10$ MeV the present results for $\sigma(\nu$ -A) are larger than the previous ones (based on the shell model) by an order of magnitude.



The cross sections of neutrino neutral-current inelastic scattering off the hot nucleus ^{56}Fe calculated within the present approach and the LSSM+RPA approach. The solid and dashed lines show the present results for the two temperatures. The dash-dotted and dash-double-dotted lines show results of the LSSM+RPA approach for the same T values.

Heavy Ion Reactions

- **Study of nuclear dynamics at low energies**
- **Mechanisms of fusion, quasifission, and multinucleon transfers**
- **Sub-barrier reactions and reactions of astrophysical interest**
- **Cluster features of fission**
- **Study of the ways to produce superheavy nuclei and unknown isotopes**

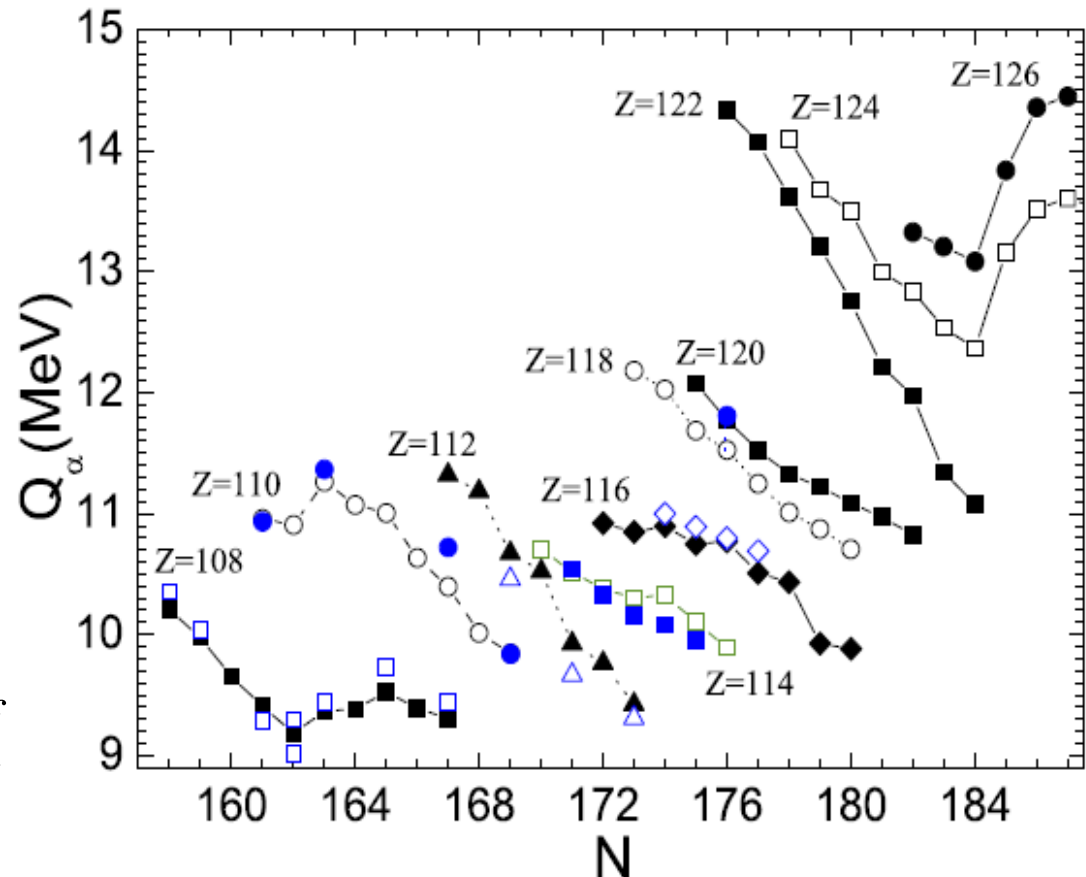
- Influence of properties of superheavies on their formation and decay

G.G.Adamian, N.V.Antonenko, R.V.Jolos, A.K.Nasirov, V.G.Kartavenko,
L.A.Malov, T.M.Shneidman, A.Sushkov, A.N.Bezbakh

Two-center shell model.

Conclusions: the next magic nucleus after ^{208}Pb has the charge $Z \geq 120$ and the half-life ($Z=120$, $N=175-179$): 1,7ms – 0,16s

Calculated (symbols connected by lines) and experimental energies of α decay of the nuclides with even Z from the range $108 \leq Z \leq 126$.

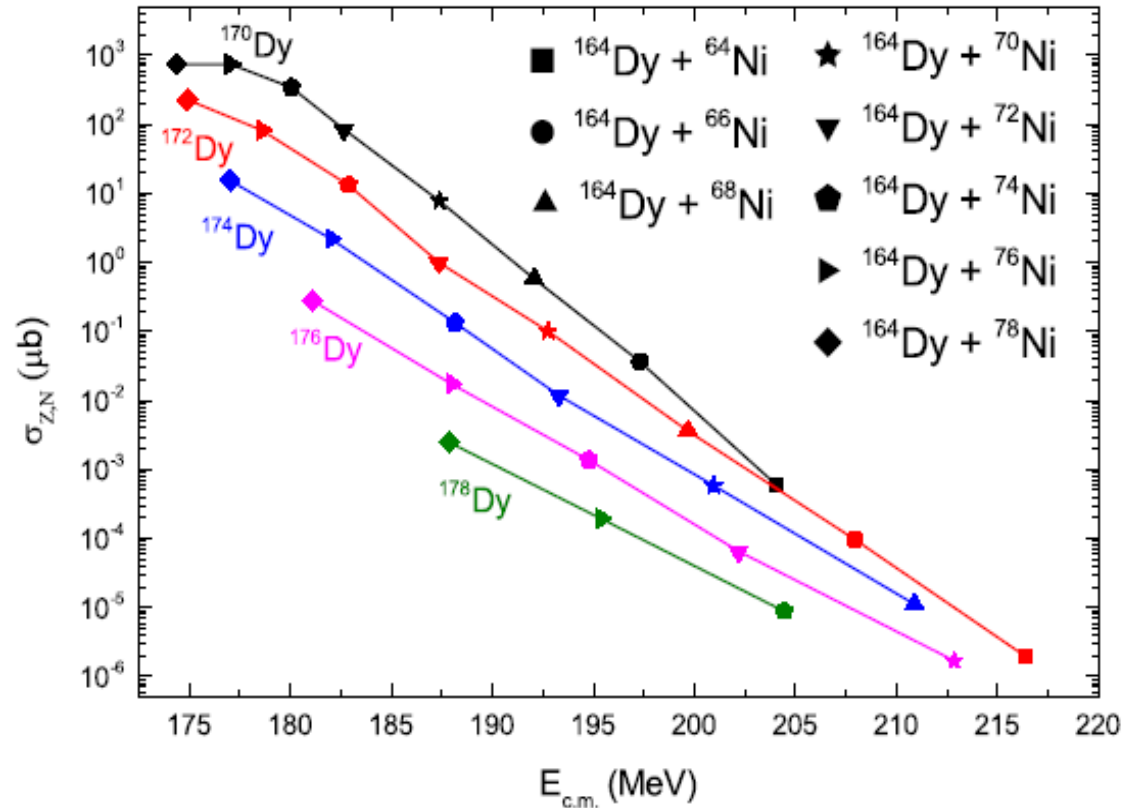


Predictions of shell closures in the region of unknown nuclei.

Study of production of new isotopes

- *in transfer reactions with stable and radioactive beams*

The predicted cross sections of the production of neutron-rich isotopes $^{170-178}\text{Dy}$ in the transfer reactions. The symbols correspond to the indicated reactions and solid lines trace the results for the same isotopes.



- *in fusion reactions with stable and radioactive beams*

For example, $^{58}\text{Ni} + ^{58}\text{Ni} \rightarrow ^{100}\text{In}$ or ^{101}Sn in $^{12}\text{C}3\text{n}$ evaporation channel.

Efimov Physics and Beyond

$^4\text{He}_3$ Predictions:

E.A.Kolganova, A.K.Motovilov, W.Sandhas,

$$\varepsilon_d = -1.3035\text{mK} \quad l_{sc} = 100.23 \text{ \AA}$$

$$E_{GS} = -126.507\text{mK} \quad E_{1ES}^* = -2.276\text{mK}$$

$$|E_{1ES}^* - \varepsilon_d| = 0.972\text{mK}$$

$^4\text{He}_3$ Measurements:

$$|E_{1ES}^* - \varepsilon_d| = 0.98 \pm 0.2\text{mK}$$

[M.Kunitski M. et. al. *Science* **348** (2015) 551]

$$\varepsilon_d = -1.1_{-0.2}^{+0.3} \text{mK} \quad l_{sc} = 104_{-18}^{+8} \text{ \AA}$$

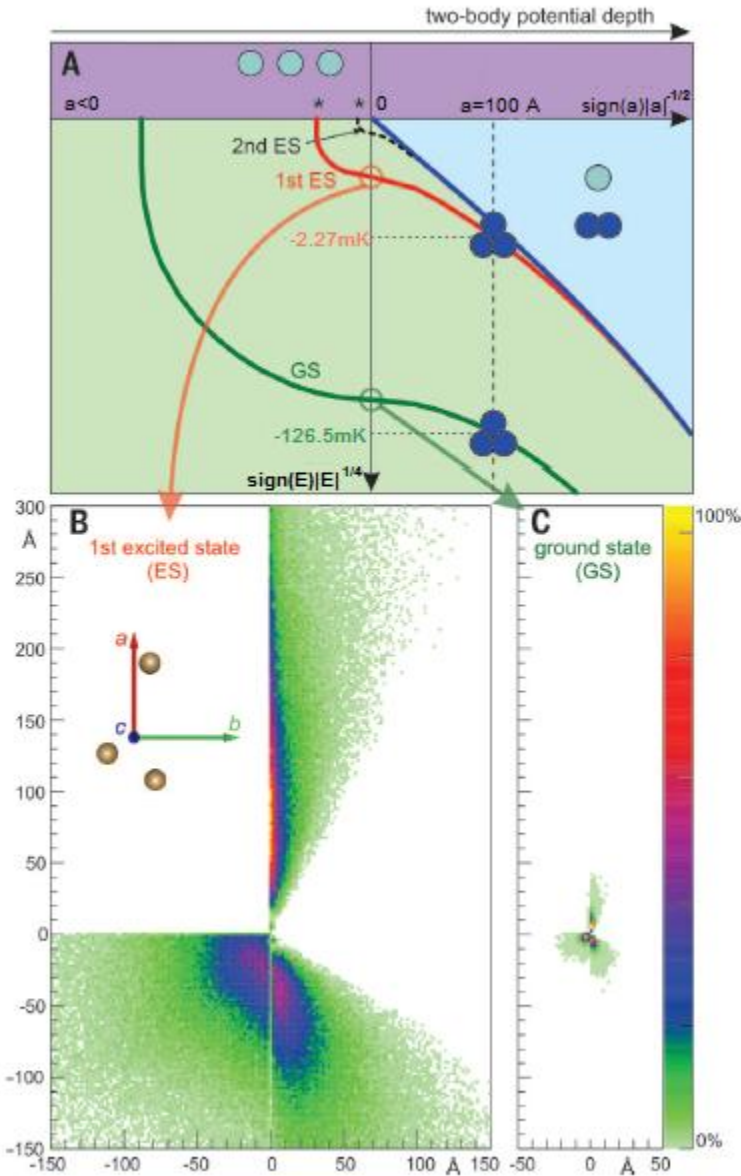
A: Dependence of the binding energies of the ground (GS) and first excited (1ST) states of the He trimer on the scattering length calculated by scaling the He-He potential.

B and C: Structure of the excited and ground states of $^4\text{He}_3$.

Future plans:

Search for Efimov resonances in three-body systems of other noble gas atoms;

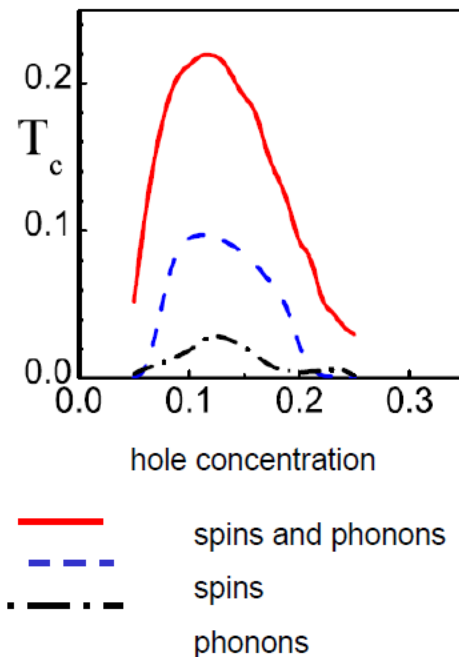
Study of universal properties of few-body systems beyond the Thomas-Efimov effects.



Spin-fluctuation kinematic mechanism of high-temperature superconductivity in cuprates

N.M. Plakida and V.S. Oudovenko

Eur. Phys. J. B 86, 115 (2013)

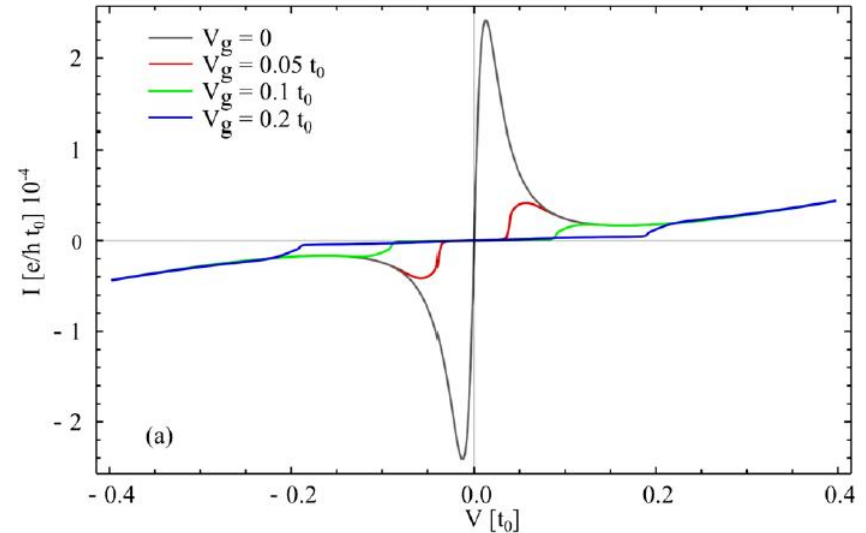
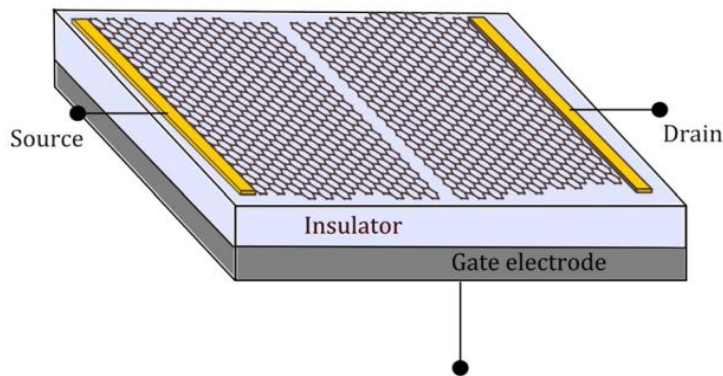


The theory of high-temperature superconductivity in copper oxides is developed. A novel pairing mechanism is discovered based on the **kinematic interaction** of composite electron operators introduced to describe strong electron correlations. Strong spin-fluctuation kinematic pairing of electrons provides high- T_c , while contributions from phonons turned out to be small. Theoretical results for superconducting T_c are close to experimental data.

Planar graphene tunnel field-effect transistor

V. L. Katkov^{a)} and V. A. Osipov

Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia



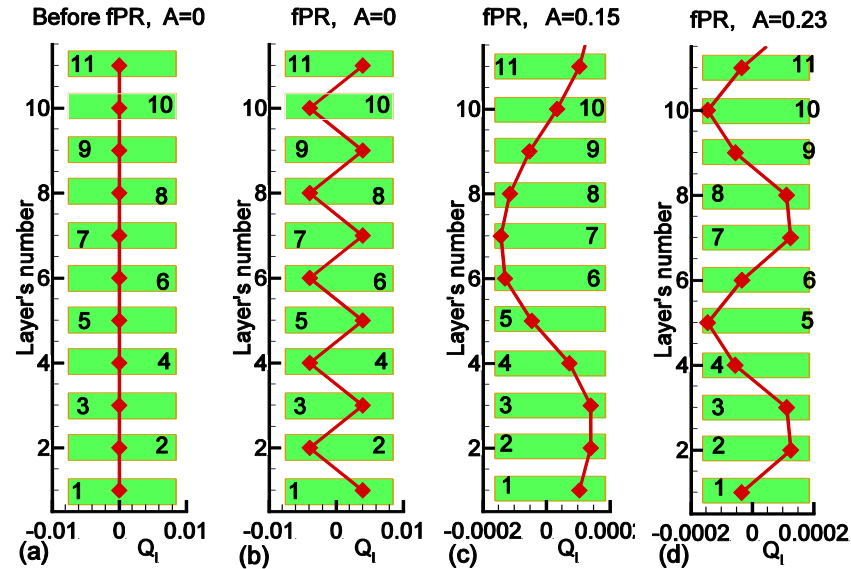
A concept for a graphene tunnel field-effect transistor has been proposed. The main idea is based on the use of two graphene electrodes with zigzag termination divided by a narrow gap under the influence of the common gate. The analysis shows that such device will have a pronounced switching effect at low gate voltage and high on/off current ratio at room temperature.

Approved Patent: RU 2014103818

Variation of Longitudinal Plasma Wavelength under Irradiation in Coupled Josephson Junctions

Intrinsic Josephson junctions in high temperature superconductors are the sources of the coherent electromagnetic radiation in terahertz region of frequencies.

A precise numerical study of phase dynamics in high-temperature superconductors under electromagnetic radiation was performed. A remarkable change in the longitudinal plasma wavelength at parametric resonance was shown. Double resonance of the Josephson oscillations with radiation and plasma frequencies leads to additional parametric resonances.



An external electromagnetic radiation can change the longitudinal plasma wavelength, excited at parametric resonance. Figure illustrates the change of plasma wavelength with increase of the amplitude of external radiation.

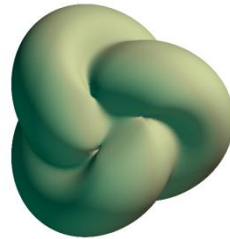
SELECTED RESULTS

Math. Phys & Condensed Matter Physics:

Twisted toroidal vortex-solitons in a Bose-Einstein condensate

New 3-dimensional twisted toroidal vortex-solitons were found in the Gross-Pitaevsky model for inhomogeneous media with repulsive nonlinearity. Configurations of this type were implemented in Bose-Einstein condensate by means of the Feshbach resonance controlled by inhomogeneous magnetic fields.

Y.V. Kartashov, B.A. Malomed, Y. Shnir, and L. Torner, Phys. Rev. Lett. 113 (2014)



Twisted toroidal field configurations are labeled by two independent winding numbers.

Dubna International Advanced School of Theoretical Physics (DIAS-TH)

Training courses for students, graduates, and young scientists in the JINR Member States and other countries.

Looking for and supporting gifted young theorists in the JINR Member States.

Organization of schools of different scales in Dubna and coordination with similar schools.

Cooperation with the JINR University Center in training students and postgraduates as well as in organizing schools for students.

Publication of lectures with the use of modern electronic equipment.

Joint Institute for Nuclear Research Bogoliubov Laboratory of Theoretical Physics



Dubna International Advanced
School of Theoretical Physics



2014

February 2 – 8

XII Winter School on Theoretical Physics



April 1 – 30

XVIII Research Workshop

Nucleation Theory and Applications



July 21 – August 1

Helmholtz International Summer School

Nuclear Theory and Astrophysical Application

August 25 – September 6

Helmholtz International Summer School

Lattice QCD, Hadron Structure

and Hadronic Matter



AGREEMENTS

- **BLTP – ICTP** (since '88)
- **BLTP – Germany** (since '91)
Heisenberg-Landau Program
- **BLTP – INFN** (since XII '95)
6 month visits to Italy
- **BLTP – CERN-TH** (since XII '95)
3 month visits to CERN
- **BLTP – Poland** (since XII '98)
Bogoliubov-Infeld Program
- **BLTP – Czech Republic** (since XII '99)
Blokhintsev-Votruba Program
- **BLTP – Romania** (since XII '03)
Titeica-Markov Program
- **BLTP – APCTP, Pohang** (since '07)
- **BLTP – Bulgaria** (since '09)
Soloviev-Khristov Program
- **BLTP – ITP CAS, China** (since VII '10)
- **BLTP – IOP VAST, Vietnam** (since VIII '11)
- **BLTP – Physical Inst., NAS, Armenia** (since '09)
Smorodinsky - Ter-Martirosyan Program

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
		2007	2008	2009	2010	2011	2012	2013	2014	2015		

April 1 - 30

XIXth Research Workshop

[Nucleation Theory and Applications](#)

April 6 - 8

Seminar dedicated to the memory of E.A. Kuraev

[Selected problems in quantum field theory](#)

June 15 - 19

Brasil - JINR Forum

[Frontiers in Nuclear, Elementary Particle and Condensed Matter Physics](#)

June 23 - 27, Prague, Czech Republic

XXIII International Colloquium

[Integrable Systems and Quantum Symmetries](#)

June 27 - July 4, Almaty, Kazakhstan

The 9th APCTP-BLTP JINR Joint Workshop

[Modern problems in nuclear and elementary particle physics](#)

June 29 - July 11

Helmholtz - DIAS International Summer School

[Dense Matter](#)

July 6 - 11

The 15th International Conference

[Strangeness in Quark Matter \(SQM-2015\)](#)

July 6 - 11, Tsakhkadzor, Armenia

The IVth International School

[Symmetry in Integrable Systems & Nuclear Physics](#)

July 13 - 18, Yerevan, Armenia

The 9th International Conference

[Quantum Theory and Symmetries \(QTS-9\)](#)

July 14 - 18

The International Conference

[Nuclear Structure and Related Topics \(NSRT15\)](#)

July 20 - 30

Helmholtz - DIAS International Summer School

[Theory challenges for LHC physics](#)

and Workshop

[Calculations for Modern and Future Colliders](#)

August 3 - 8

International Workshop

[Supersymmetries and Quantum Symmetries \(SQS'2015\)](#)

August 27 - September 4, Horny Smokovec, Slovakia

VI International Pontecorvo

[Neutrino Physics School](#)

September 8 - 12

XVIth International Workshop

[High Energy Spin Physics \(DSPIN-15\)](#)

September 21-25

4th South Africa - JINR Symposium

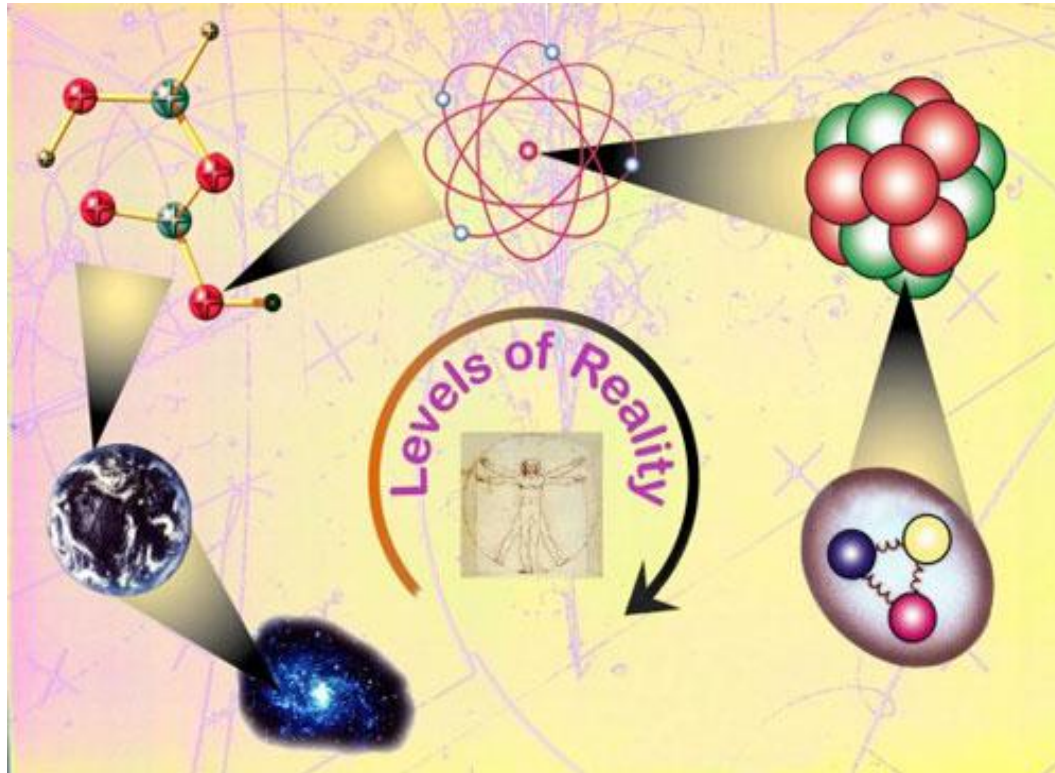
[Few to Many Body Systems: Models and Methods and Applications](#)



DUBNA
JINR
BLTP
Welcome!



Thank you for your attention!

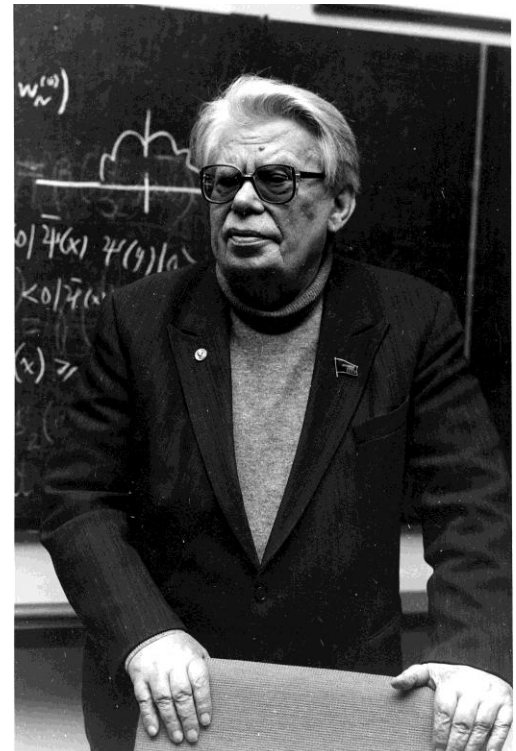


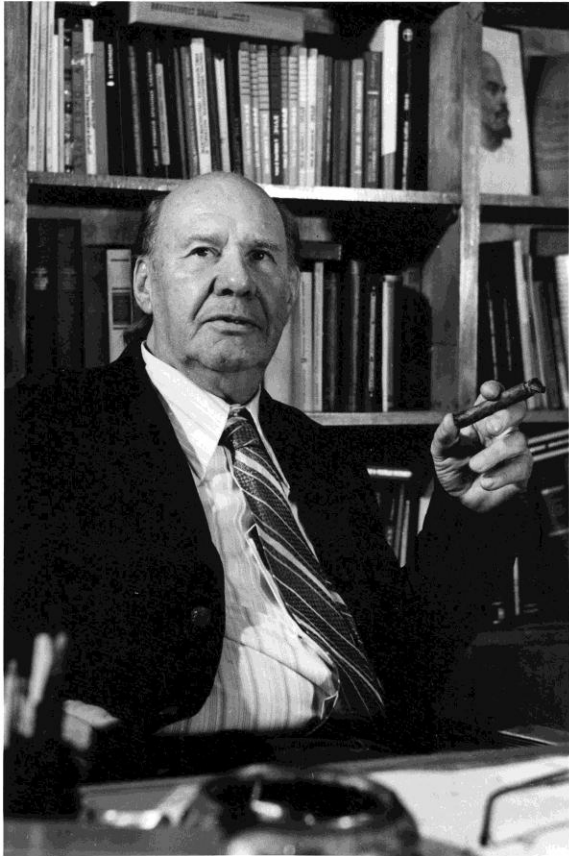
Nikolai Nikolaevich Bogoliubov (1909–1992) is a distinguished scientist in the field of physics and mathematics. His scientific activity began in Kyiv (1923–1947) and then continued in Moscow (since 1949) and Dubna (since 1956). Main scientific results in the fields:

- Nonlinear mechanics: asymptotic methods, stability theory ;
- Statistical physics: kinetic equations, quasiaverages for systems with spontaneously broken symmetries;
- Quantum statistics: microscopic theory of Bose-gas superfluidity, microscopic theory of superconductivity ;
- Quantum field theory: axiomatic scattering matrix, general renormalization theory, renormalization group theory, proof of dispersion relations;
- Elementary Particle Theory: "quark bag" model, quantum number "colour".

N.N. Bogoliubov's scientific activity began at the age of 14 –15. His major independent results were obtained when he was 20–25.

N.N. Bogoliubov's scientific activity is specified by considerable mathematical culture and directness to solution of concrete problems of natural science.





Dmitrii Ivanovich Blokhintsev (11.01. 1908 – 27.01.1979), one of the pioneers of atomic science and technology in USSR, the organizer and the first director of the JINR.

Main scientific results in the fields:

- Quantum mechanics
- Acoustics of an inhomogeneous moving medium
- Neutron physics
- Quantum field theory
- Particle physics

1954 – the scientific supervisor of creation and putting into operation of the world first atomic power station.

1956- 1965 – the JINR Director

1965 – 1979 – Director of Lab of Theoretical Physics

