

APPROVED BY
JINR Vice Director

“ ” 2018

**SCIENTIFIC AND TECHNICAL JUSTIFICATION FOR OPENING A NEW THEME
OR FOR EXTENDING THEME
to be included in the
TOPICAL PLAN FOR JINR RESEARCH FOR 2019–2023**

Theme code

Laboratory BLTPh

**Department Scientific department of
Theory of fundamental interactions**

Research area: Theoretical and Mathematical Physics

Theme title “Fundamental interactions of fields and particles”

Theme leaders: D.I. Kazakov, O.V. Teryaev

Abstract

The investigations and solutions of the wide circle of problems of particle physics and quantum field theory are expected in the framework of Theme “Fundamental interactions of fields and particles”.

Theory of fundamental interactions, whose main mathematical tool is the quantum field theory, is the main instrument of microworld physics investigations, which are necessary for planning and interpretation accelerator and non-accelerator experiments, construction of physical picture of the World and realization of its numerous applications.

Theory of fundamental interactions is deeply interconnected with various investigations in the fields of nuclear, atomic, statistical and mathematical physics.

The investigations in the framework of new theme will be closely coordinated with experimental programs of JINR, CERN and other international and Russian centers. The special attention will be paid to the problems, important for successful realization of NICA project, both in the fields of heavy ion physics and hadron structure.

The necessary background of theory of fundamental interactions is the investigation of topical problems of quantum field theory, including the theoretical investigations of the amplitudes, formfactors and integrability problems in the theories with extended supersymmetry, studies of AdS-CFT correspondence and correspondence of higher spin and critical behaviour theories.

The important direction is the study of phenomenology of the (non)supersymmetric extensions of Standard model: two-doublet model, Minimal Supersymmetric Standard Model (MSSM) and its extensions like Next-to-minimal, R-parity violating etc.

New high-precision predictions will be deduced for the cross sections of the electroweak particle interactions studied at modern and planned high-energy colliders, including the LHC, ILC, and FCC. A high accuracy of theoretical predictions will be provided by taking into account radiative corrections within the SM framework. Emphasis will be placed on processes involving electroweak vector bosons, the top quark, and the Higgs boson, the study of which are of ultimate importance for verification of the Standard Model and new physics searches

The neutrinos remain one of the most enigmatic of the fundamental fermions and we still don't know the answers to several undeniably principal questions. The subject of the main interest are absolute neutrino mass scale, their hierarchy (spectrum) and mechanism of the mass generation, physical nature of the neutrino fields (Dirac, Majorana, or ELKO spinors), mechanism of the CP violation in the neutrino sector, fundamental nature of the neutrino flavor oscillations in vacuum and matter (quantum-mechanical flavor-state mixing or interference of field-theoretical macroscopic Feynman amplitudes). A natural laboratory to study fundamental properties of neutrinos with help of beta decay, electron capture, double beta decay, double electron capture, scattering of neutrinos on nucleons, nuclei and electrons is an atomic nucleus.

Recently, understanding of three-dimensional (3D) structure functions of nucleons in non-perturbative QCD became one of hot topics in hadron/particle physics. The principle intention of these studies is, first, to apprehend the source of nucleon spin which should include the contributions emanating from partonic orbital-angular-momenta. At present, the different theoretical and experimental studies have mostly been focused on the transverse-momentum-dependent parton distributions (TMDs). The central role will be played by the theoretical support of experimental program of detector SPD at NICA. Because of relatively moderate energies and momentum transfer the QCD analysis of polarized and unpolarized parton distributions in the analytic perturbation theory is of special importance.

We plan the further development of the program of calculation of observables in the exclusive processes with the participation of hadrons containing heavy c- and b-quarks, and the physical characteristics of semileptonic decays of hadrons with open-charm (*D*-mesons, Λ_c -baryons) in connection with experiments carried out by collaborations Belle (Japan), BESIII (China), as well as for future experiments on a new Super Charm-Tau-factory in Novosibirsk.

The important complementary activity is the use of low energy processes aimed to check the Standard Model, the calculation of hadronic contributions to the hyperfine splitting of the levels in muonic hydrogen atoms and to the anomalous magnetic moment of muon, the study of the processes of meson creation in e^+e^- annihilation and tau-lepton decay in an extended Nambu–Jona-Lasinio model.

The interplay of physics of fundamental interactions and atomic physics is realized in the determination spectrum of ro-vibrational states in molecular ions of hydrogen isotopes with a relative precision 10^{-12} within the nonrelativistic QED approximation. That would allow to improve values of the Rydberg constant, electron, proton and deuteron masses, and to give independent determination of the proton charge radius provided that corresponding experiments will be carried out.

The crucially important direction is the theory of hadronic medium at extreme conditions, which is of unquestionable general interest and is also the realization of theoretical support of the experimental program of NICA complex (MPD and BM@N detectors). It includes study of topological properties of

quark-gluon plasma (QGP) by lattice QCD methods, calculation of temperature dependence of topological susceptibility in the critical region, studies of anomalous transport in QGP, including the mechanisms of global baryon polarization, calculation of gluon and quark propagators and spectral functions, transport coefficients, investigation of chiral symmetry restoration mechanism. For NICA energies the investigation of critical phenomena in dense quark-gluon matter for SU(2) (direct lattice calculations) and SU(3) (analytic continuation) gauge groups is of special importance.

List of activities

Results expected upon completion of the theme

The new theoretical approaches for the description of the processes at the accelerators in the wide energy domain, described by various ingredients of Standard Model and its extensions, will be developed and applied in the specific calculations. The understanding will be essentially deepened and high precision predictions will be made for electroweak theory, neutrino physics, quantum chromodynamics of the processes with the account for spin degrees of freedom, physics of exclusive processes of hadrons, containing heavy quarks, physics of hadronic matter at extreme conditions.

Participants from JINR

	Laboratory	Participants
1.	Quantum field theory and physics beyond the Standard Model	Kazakov D.I. Gladyshev A.V. Bednyakov A.V.
	BLTPh	Kotikov A.V, Onischenko A.I, Pikelner A.F, Baushev A.N, Gnatch M., Remetsky R., Mizhishin L., Vladimirov A.A, Kozlov G.A, Das Ch. R., Tolkachev D.M., Borlakov A.T, Yakhibbaev R.M. + 5 students
	LIT	Gerdt V.P, Tarasov O.V.
	DLNP	Bednyakov V.A., Kalinovskaya L.V., Hramov E.V., Yakushev E.V., Tkachev L.G., Budagov Yu.A.
2.	Electroweak theory and neutrino physics	Arbuzov A.B. Naumov V.A. Shimkovits F.
	BLTPh	Dorokhov A.Ye., Bystritskiy YU.M., Byt'yev V.V., Bednyakov A.V., Pikel'ner A.F., Seylkanova G. Babich A., Kuz'min K.S., Krivoruchenko M.I., Sokal'skiy I.A., Shkirmanov D.S, + 1 student
	VBLHEPh	Zykunov V.A., Kakorin I.D.
	DLNP	Kalinovskaya L.V., Sadykov R.R., Saponov A.A., Dydyshko Ye.V. + 2 students
3.	QCD and spin / 3D hadron structure	Anikin I.V. Teryaev O.V.
	BLTPh	Efremov A.V. Goloskokov S.V, Mikhailov S.V.,

		Selyugin O.V., Klopot YA., Volchanskiy N.I., Kotlozh D.V., Silenko A.J., Byt'yev V.V., Deka M., Pivovarov A.A., Prokhorov G.Yu., Oganessian A.G. + 6 students
	VBLHEPh	Tsenov R., Nagaitsev A.P.,
	DLNP	Guskov A.V.,
4	Strong interactions phenomenology and precision physics	Ivanov M.A. Korobov V.I. Dorokhov A.Ye.
	BLTPh	Arbuzov A.B, Volkov M.K., Gerasimov S.B., Kochelev N.I., Sidorov A.V., Osipov A.A., Bystritsky Yu.M., Pavel H.-P., Alvarez D., Nurlan K., Ganbold G., Martynovich L., Surovtsev Yu.S., Eliseev S.M., Nagy M., Zhaugasheva S.A., Bekbaev A.K., Isadykov A.N., Tyulemisov Zh., and 5 students
5.	Theory of hadronic matter under extreme conditions	Blaschke D., Braguta V.V. Kolomeitsev E.E. Nedelko S.N.
	BLTPh	Alvarez-Castillo D., Deka M., Dorkin S., Dorokhov A.E, Frizen A.V., Golubtsova A.A., Gnatic M., Hasegawa M., Ilgenfritz M., Ivanov M., Captar L., Khvorostukhin A.S., Korchagin N.S., Kotov A., Maslov K., Melzhik V., Nikolsky A., Pandiat S., Parvan A., Snigirev A. M., Teryaev O.V., Toneev V.D., Voronin V.E., Voskresensky D., Zinoviev G.M. + 5 students
	LIT	Ayryan A.S., Grigoryan H., Kalinovsky Yu.L., Nikonov E.
	VBLHEPh	Rogachevsky O.V., Voronyuk V.

Participating countries, institutes and organizations

Country or Organization	City	Institute or Laboratory	Participants	Status
Austria	Graz	University	Hilger T.	Exchange visits
Argentina	Buenos Aires	University	Cirilo-Lombardo D.	Collaboration
Armenia	Yerevan	RAU		
Belarus	Gomel	Tech. University	O.P. Solovtsova, V.I. Lashkevich	Collaboration
Bulgaria	Sofia	INRNE BAS	Bakalov D.D. + 2 people D. Stamenov, E. Christov	Collaboration
Great Britain	Liverpool	University of Liverpool	Andreopoulos C.	Collaboration
Vietnam	Hanoi	Institute of Physics, Vietnamese Academy of Science and Technology	Long Kh.N., Hue L.T., Khan N.S.	Collaboration

Egypt	Cairo	WLAPP	Tawfik A. + 2 people	Collaboration
Germany	Hamburg	University	Veretin O.L., Kniel B.A.	Collaboration
	Heidelberg	<u>Max-Planck-Institut für Kernphysik</u>	Blaum K.,	Exchange visits
	Heidelberg	University	J.M. Pavlovsky + 3 people	Agreement
	Giessen	University	K. Fisher, L.von Smekal, B.-J. Shafer, W. Kassing + 2 people	Agreement
	Darmstadt	GSI	Bratkovskaya E. + 3 people	Agreement
	Dresden	Tech. University Dresden Institute of Theoretical Physics	B.Kämpfer	Collaboration
	Leipzig	University	Bordag M.	Collaboration
	Regensburg	University	Buividovich P., V.M. Braun, A.A. Vladimirov, S.M. Strohmaier, A.N. Manashov	Exchange visits
	Tübingen	University of Tübingen, Institute of Theoretical Physics	Faessler A.	Collaboration
	Zeuthen	DESY	Riemann T., Riemann S.	Collaboration
	Bochum	University	Stefanis, N., Polyakov, M., Epelbaum E.	Collaboration
	Düsseldorf	University	Schiller Sh. + 5 people	Collaboration
	Garching bei Munchen	MPQ	Hori M.	Collaboration
	Mainz	University	Körner J.	Collaboration
	Mainz	Helmholtz Inst.	Maas F. + 2 people	Collaboration
	Tübingen	University	Gutsche T. + 1 person	Collaboration
	Frankfurt	University	Bratkovskaya E.+ 1 pers.	Collaboration
India	Bhubaneswar	Institute of Physics	A. Srivastava	Collaboration
	Kanpur	IIT	D. Chakrabarti + 2 people	Collaboration
Italy	Pisa	INFN	Venanzoni G., D'Elia M. + 1 pers.	Collaboration
	Triest	SISSA/INFN	Petcov S.T.	Collaboration
	Bari	INFN, Sezione di Bari	Lisi E.	Collaboration
	Naples	University	Santorelli P., Chan T.T.	Collaboration
	Parma	University	Trentadue L.	Collaboration
	Bologna	University	Kamenshchik A.Yu.	Collaboration
	Rome	INFN Frascati	M.P. Lombardo	Collaboration
Spain	Valencia	University of Valencia	Alvarez-Ruso L.	Collaboration

	Madrid	Instituto de Estructura de la Materia	Sarriguren P.	Collaboration
China	Beijing	IHEP	Wong Ping	Collaboration
	Changchun	Jilin University	Fang D. L.	Collaboration
	Wuhan	WIPM CAS	Zhong Zh.-K. + 3 people	Collaboration
		University	Yan Z.-C. + 2 people.	Collaboration
	Langzhou	IMP	Zhang P.	Collaboration
Netherlands	Amsterdam	University	Ubakhs V. + 5 people. Mulders P.	Collaboration
Poland	Krakow	NINP PAS	Bronevsky V., Wons Z. Kaminski R. Adamczak A.	Collaboration
	Lublin	Department of Theoretical Physics, Maria Curie-Skłodowska University	Gozdz A.	Collaboration
	Opole	Tech. University	A. Kotlorz	Collaboration
	Warsaw	UW, NCBJ	Szymanowski L., Wagner J., Pedrack A.	Collaboration
	Krakow	JU, NINP PAS	Golec-Byrnat K., Motyka L.	Exchange visits
	Warsaw	University	Pahucki K.	Collaboration
Russia	Moscow	MSU	Sveshnikov K.A.	
	Moscow	MEPhI	Petrukhin A.A.	
	Moscow	SINP MSU	Boos E.E, Arbuzov B.A., Baranov S.P.	Exchange visits
	Moscow	Computing Center of RAS	Faustov R.N.	Collaboration
	Moscow, Troitsk	INR RAS	Kataev A.L., Kulagin S.A.	Collaboration
	Moscow	NRC "Kurchatov Institute"	Skorokhvatov M.D.	Collaboration
	Moscow	ITEP NRC KI	Nadezhin D.K, Yudin A.V., Zakharov V.I., Lushchevskaya E.V.	Collaboration
	Protvino	IHEP NRC KI	Garkusha V.I., Sokolov A.A., Bornyakov V.G.	Collaboration
	Vladivostok	FEFU	Nakamura A. + 1 pers.	Exchange visits
	Gatchina	PNPI NRC KI	Vorobiev A.A., Kim V.T., Novikov Yu.N.	Collaboration
	Dubna	University "Dubna"	Kopylova T.V.	Collaboration
	Samara	University	Martynenko A.P., Martynenko F.A., Saleev V.A. + 5 people	Collaboration
	Saratov	University	Smolyansky S.A.	Collaboration
	Novosibirsk	NSU	Ivanov D.Yu., Grabovsky A.V.	Exchange visits, Collaboration
	Irkutsk	ISTU RAS	Radzhabov A.E.	Collaboration

	St. Petersburg	SPbSU	V.A. Andrianov, M. Kompaniets	Collaboration
	Tomsk	University	Zhevlakov A.S.	Collaboration
	Moscow	ПУДН	Севастьянов Л.А.	Protocol
Romania	Bucharest	IFIN-HH, DFT	D.V. Anghel, I.Caprini	Exchange visits
Slovakia	Bratislava	Comenius University	Dvornicky R. Stefanik D.	Collaboration
	Bratislava	IP SAS CU	Dubnička S. + 5 people Dubníčková A.Z.	Collaboration
	Košice	IEP SAS	Hnatič M. + 3 people	Collaboration
	Banska Bystrica	University	Tomašik B. + 3 people	Collaboration
USA	Pittsburgh	University of Pittsburgh	Dytman S.	Collaboration
	Medford	Tufts University	Gallagher H., Wolcott J.	Collaboration
Ukraine	Kiev	INR	Danevich F., Tretyak V.I.	Collaboration
	Kiev	ITF NASU	Bugaev K., Karpenko Yu.+ 2 people	Collaboration
France	Paris	LKB ENS	Iliko L. + 5 people	Collaboration
	Saclay	SPhN CEA	E. Tomasi-Gustafsson+ 2 people	Collaboration
	Nantes	University	J. Aichelin + 1 person	Exchange visits
Czech Republic	Řez	Institute of Nuclear Physics ASCR	E. Truhlík J. Adam Jr. M. Tater, Bydzovski P	Collaboration
	Prague	IP AVCR	Zavada P.	Collaboration
Chile	Valparaiso	Universidad Tecnica Federico Santa Mariya	Kovalenko S. Lyubovitsky V.E. + 2 people	Collaboration
Sweden	Lund	UL	Pasechnik R.	Collaboration
South Africa	Cape Town	University	Cleymans J. +1 person	Exchange visits
Republic of Korea	Seoul	Department of Physics, Soongsil University	Cheoun M.-K.	Collaboration
	Incheon	Inha University	Hyun-Chul Kim	Collaboration
Japan	Tsukuba	KEK	Kumano,S,	Collaboration

Time frame of the theme 2019 – 2023

Total estimated cost of the theme

№№	Activities	Total cost	Costs per years (thousand USD)				
			1st year	2nd year	3rd year	4th year	5th year
1.	Salary	10401,9	1772,2	1949,4	2105,4	2231,6	2343,3
2.	Unified social tax	3141,3	535,2	588,7	635,8	673,9	707,7
3.	Social Fund	676,2	115,2	126,7	136,9	145,1	152,3
4.	The international cooperation	750,0	150,0	150,0	150,0	150,0	150,0
5.	Materials	250,0	50,0	50,0	50,0	50,0	50,0
6.	Equipment	400,0	80,0	80,0	80,0	80,0	80,0
	Total	15619,4	2702,6	2944,8	3158,1	3330,6	3483,3
7.	Infrastructure BLTP	4288,8	776,2	815,9	855,7	898,5	943,4
	Total	19908,2	3478,8	3759,8	4013,8	4229,1	4426,7
8.	Infrastructure JINR	6761,1	1151,9	1267,1	1368,5	1450,5	1523,1
	Total	26179,3	4630,7	5026,9	5382,3	5679,6	5949,8

AGREED:

JINR Chief Scientific Secretary

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 “ ” _____ **2018**

Head of Planning and Finance Department

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 “ ” _____ **2018**

Head of Science Organization Department

_____/_____
 “ ” _____ **2018**

Laboratory Director

_____/_____
 “ ” _____ **2018**

Laboratory Scientific Secretary

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 “ ” _____ **2018**

Laboratory Economist

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 “ ” _____ **2018**

Theme leader

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