**Summary of implementation of** [Theme   
``Theory of Fundamental Interactions''](http://wwwinfo.jinr.ru/plan/ptp-2014/a431113.htm) **(01-3-1113-2014/2018) in 2014-2018**

Possible new physics (NP) effects have been studied in the exclusive B-decays. For this purpose, some extension of the Standard Model was suggested by means of using right-handed and tensor currents. The new transition form factors were calculated in the framework of a covariant quark model. The constraints on NP Wilson coefficients have been established by employing measurements of the ratios of relevant branching fractions.

The possibility that the new double charm state Ξcc++ can be attributed to the decay chain Ξcc++ → Σc++ (→ Λc+ π+) + ̅K\*0 (→ K− π+) was discussed in great detail. The hypothesis can be tested experimentally by looking at the decay distributions of the particles involved in the cascade decay.

The differential rate and the forward--backward asymmetries on the lepton and hadron side for the rare baryon decays Λb → Λ l+l− (l=e,μ,τ) and Λb → Λγ were calculated within the covariant quark model. By using helicity methods a three--fold joint angular decay distribution for the subsequent cascade decay has been written down in the explicit form.

Refined values of the fundamental transition frequencies in the hydrogen molecular ions were calculated, which allow to determine fundamental constants such as the Rydberg constant, and proton to electron mass ratio with significant accuracy. And potentially it allows to clarify situation with the proton rms charge radius .

The dark matter sector was considered within the constrained minimal supersymmetric SM (CMSSM) and the next-to-minimal supersymmetric SM (NMSSM). In the dark matter sector the two models are quite orthogonal: in the CMSSM the WIMP is largely a bino and requires large masses from the LHC constraints. In the NMSSM the WIMP has a large singlino component and is therefore independent of the LHC SUSY mass limits. The light NMSSM neutralino mass range is of interest for the hints concerning light WIMPs in the Fermi data. Such low mass WIMPs cannot be explained in the CMSSM. Furthermore, prospects for discovery of XENON1T and LHC at 14 TeV are given

A manifestly gauge-independent analysis of the vacuum stability in the Standard Model (SM) including two-loop matching, three-loop renormalization group evolution, and pure QCD corrections through four loops was performed. All these ingredients are exact, except that light-fermion masses are neglected. We in turn apply the criterion of nullifying the MS Higgs self-coupling and its beta function and the recently proposed consistent method for determining the true minimum of the effective Higgs potential that also avoids gauge dependence. Exploiting our knowledge of the Higgs-boson mass, an upper bound on the pole mass of the top quark was derived by requiring the SM to be stable all the way up to the Planck mass scale and the theoretical uncertainty was estimated conservatively. This bound is compatible with the mass quoted by the Particle Data Group at the 1.3σ level.

Leading four-loop electroweak corrections to the beta-function of the strong coupling in the Standard Model (SM) were obtained. The well-known approach for calculation of "threshold" corrections to the running strong coupling and b-quark mass in QCD was extended to include electroweak corrections. It was demonstrated how the behaviour of perturbative series could be improved by utilising the above-mentioned approach.

A systematic study of the leading ultraviolet divergences for the on-shell scattering amplitudes in gauge field theories with maximal supersymmetry in dimensions D = 6, 8 and 10 is performed. The all loop summation of the leadingdivergences is performed with the help of the differentialequations which are the generalization of the RG equations for non-renormalizable theories. Numerical solutions of these equations in the general case are obtainedin D=6, 8 and 10 dimensions. The key issue is that the summation of infinite seriesfor the leading and the subleading divergences does improve the situation and doesnot allow one to remove the regularization and obtain the finite answer. This meansthat despite numerous cancellations of divergent diagrams these theories remain non-renormalizable.

Truncated Mellin moments (TMM) approach is constructed to study deep inelastic scattering in lepton-hadron collisions at the natural kinematic constraints. Generalized TMM obtained by multiple integrations as well as multiple differentiations of the original parton distribution also satisfy the DGLAP equations with the simply transformed evolution kernel. Using appropriate classes of TMM, the generalized Bjorken sum rule is constructed that allows to determine very effectively the Bjorken sum rule value from the experimental data in a restricted kinematic range. The approach is applied to COMPASS data.

The general theory of spinning particles with electric and magnetic dipole moments moving in arbitrary electromagnetic, inertial and gravitational fields is developed. Both the quantum-mechanical and classical dynamics is investigated. The dynamics of a spinning particle in a gravitational wave is considered and the prospects of the use of the magnetic resonance setup for the registration of the gravitational wave via its impact on the spin dynamics are analyzed.

In connection with new COMPASS results, the single spin asymmetry which probes gluon poles together with chiral-odd and time-odd functions is proposed. The relevant pion production as a particular case of Drell-Yan-like process has been discussed. For the meson-induced Drell-Yan process, the analog of the twist three distribution function, which is a collinear function in inclusive channel, is modeled by means of two non-collinear distribution amplitudes which are associated with exclusive channel. This modelling demonstrates the fundamental duality between different factorization regimes

The light-cone sum rules for the electromagnetic nucleon form factors including the next-to-leading-order corrections for the contribution of twist-three and twist-four operators and a consistent treatment of the nucleon mass corrections are considered. The form factors are thus expressed in terms of nucleon wave functions at small transverse separations, called distribution amplitudes, without any additional parameters. The distribution amplitudes can be extracted from the comparison with the experimental data on form factors and compared to the results of lattice QCD simulations. A selfconsistent picture emerges, with the three valence quarks carrying 40%:30%:30% of the proton momentum,.

The complete lattice calculation of the quark and glue momenta and angular momenta in the proton is performed. These include the quark contributions from both the connected and disconnected insertions. The chirally extrapolated u and d quark momentum/angular momentum fraction is found to be 0.64(5)/0.70(5), the strange momentum/angular momentum fraction is 0.024(6)/0.023(7), and that of the glue is 0.33(6)/0.28(8),

The development of the analytic perturbation theory was continued. It was applied to renormalization group equation for the evolution of the moments of the structure functions. A new approximation is proposed for the contour of the stationary phase of the Mellin-Barnes integrals in the case of its finite asymptotic behavior. It was used to study the evolution of the F3 structure function. An NLO QCD analysis of the final HERMES data on pion multiplicities was presented and a new set of pion fragmentation functions is extracted from the best fit to the data.

The complete result for the light-by-light contribution to the muon anomalous magnetic moment was calculated in the framework of the nonlocal SU(3) x SU(3) chiral quark model. The full kinematic dependence of vertices with off-shell mesons and photons in intermediate states in the light-by-light scattering amplitude is taken into account. All calculations are elaborated in explicitly gauge-invariant manner. All relevant contributions of intermediate mesons and and the dynamical quark loops in the leading order in the 1/Nc expansion were taken into account. These results are important for reduction of the theoretical uncertainty in the muon anomalous magnetic moment.

The extended Nambu-Jona-Lasinio model was used to construct theoretical description of a large number of low-energy meson production processes in colliding electron-positron beams and in tau lepton decays. The processes considered occur via intermediate scalar, vector, and axial-vector mesons in the ground state and in the first radial excited state. Comparisons with experimental data and alternative phenomenological strong interaction models were performed. Theoretical predictions for modern experiments are provided.

Combining the spin-dependent dispersion Gerasimov-Drell-Hearn sum rule, the iso-vector, photo-excitation states projecting Cabibbo-Radicati sum rule, and the relativistic dipole-moment-fluctuation (or generalized Gottfried) sum rule with the three valence quark configuration of nucleons taken into account for the composition of the ground and the excited states of the nucleon, the relevant moments of the distribution and correlation functions of the quark electric dipole moment operators in the nucleon ground state are expressed via the experimentally measurable nucleon resonance photo-excitation amplitudes. These functions are relevant for checking detailed quark-configuration structure of the nucleon state vector.

A field-theoretical approach to neutrino oscillation phenomenon was developed. The approach treats the in and out lags of the Feynman macroscopic diagrams as covariant wave packets and the neutrino mass eigenfields – as propagators connecting the source and detector vertices of the macrodiagram. The predicted quantum decoherence corrections to the (anti)neutrino flavor transition probabilities are now a subject of studies in reactor antineutrino experiments. An extension of the Grimus-Stockinger theorem is developed which provides corrections to the classical inverse-square law behavior of the neutrino event rates at short distances between the source and detector. These corrections may be relevant for resolving the so-called reactor antineutrino anomaly.

A global statistical analysis to the world's data on neutrino-nucleus interactions was performed, with the aim of extracting a set of phenomenological parameters (axial mass of the nucleon, cuts in invariant mass of the final-state hadrons, etc.) important for the data processing and interpretation of the neutrino oscillation data. A phenomenological analysis of the hadron multiplicities in neutrino collisions with hydrogen and deuterium targets was carried out. A substance development and optimization of the Monte Carlo neutrino generator GENIE was realized. Among other things, an extended Rein-Sehgal model for single-pion neutrinoproduction through baryon resonances and the running axial mass model are incorporated into the generator. The current GENIE release is used in essentially all modern accelerator neutrino experiments.

A novel effect in 0νββ decay was investigated. Its underlying mechanisms take place in the nuclear matter environment. The neutrino exchange mechanism is studied. It was demonstrated a possible impact of nuclear medium via Lepton Number Violating (LNV) 4-fermion interactions of neutrino with quarks from decaying nucleus. The net effect of these interactions is generation of an effective in-medium Majorana neutrino mass matrix. The enhanced rate of the 0νββ-decay can lead to the apparent incompatibility of the 0νββ-decay observations with the neutrino mass restricted by the β-decay and cosmological data. The effective neutrino masses and mixing are calculated for the complete set of the relevant 4-fermion neutrino-quark operators. Using experimental data on the 0νββ decay in combination with the β-decay and cosmological data the characteristic scales of these operators was estimated: ΛLNV ≥ 2.4 TeV.

The Three-fluid Hydrodynamics-based Event Simulator Extended by UrQMD final State interactions (THESEUS) has been constructed and its performance with basic results is decribed in a collaborative publication. The program is the first and only (so far) that can provide event simulation in the energy range of NICA and FAIR with the equation of state of matter as an input, so that inparticular the question of typical signatures for a first order phase transition, as opposed to a crossover transition, can be investigated with it. As examples are given: the proton rapidity distribution and flow observables.

A mean field approach to QCD vacuum describable in terms of a statistical ensemble of almost everywhere homogeneous Abelian (anti-)self-dual gluon fields represented as domain wall networks was refined.. Strong, electromagnetic, and weak interactions of mesons are represented in the effective action in terms of nonlocal n-point interaction vertices given in analytical form. New systematic results for the mass spectrum and decay constants of radially excited light, heavy-light mesons, and heavy quarkonia were presented. Transition form factors of pseudoscalar mesons were studied consistently with mass spectra. Within the framework of this approach a polarizing effects in QCD vacuum due to the strong alactromagnetic field were studied. It is shown that strong electromagnetic fields can play a catalysing role for deconfinement in heavy ion collisions.

Relativistic magnetohydrodynamics (RMHD) simulations were carried out to study the effects of this magnetic field on the evolution of the plasma and on resulting flow fluctuations in the ideal RMHD limit. The results show that the magnetic field leads to enhancement in elliptic flow for small impact parameters while it suppresses it for large impact parameters. It is demonstrated that magnetic field in localized regions can temporarily increase in time as evolving plasma energy density fluctuations lead to reorganization of magnetic flux. The situation of nontrivial magnetic field configurations arising from collision of deformed nuclei is considered, and is shown to lead to anomalous elliptic flow.

The study of the confinement/deconfinement transition in lattice SU(2) QCD at finite quark density and zero temperature was performed on a lattice with rooted staggered fermions at a lattice spacing a=0.044 fm. This small lattice spacing allowed one to reach very large baryon density (up to quark chemical potential 2000 MeV) avoiding strong lattice artifacts. In the region of chemical potential about 1000 MeV the confinement/deconfinement transition was observed for the first time. After the deconfinement is achieved, a monotonous decrease of the spatial string tension is seen which ends up with vanishing value at the chemical potential about 2000 MeV. These observations lead to the conclusion that the confinement/deconfinement transition at finite density and zero temperature is quite different from that at finite temperature and zero density. The results indicate that in very dense matter the quark-gluon plasma is in essence a weakly interacting gas of quarks and gluons without a magnetic screening mass in the system, sharply different from a quark-gluon plasma at large temperature.

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