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RELATIVISTIC NUCLEAR PHYSICS & QUANTUM CHROMODYNAMICS

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LONG RANGE RAPIDITY CORRELATIONS BETWEEN THE TRANSVERSE MOMENTUM AND THE MULTIPLICITIES IN LIGHT-NUCLEI COLLISIONS

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During recent decades the long-range rapidity correlations phenomenon was studied both experimentally and theoretically in relativistic nuclear physics. The correlations between the multiplicities (n-n) and the transverse momentum and the multiplicity (pT-n) of charge particles are analyzed in the framework of the simple string inspired model with two types of sources [1]. The sources of the first type (primary emitters) correspond to the initial strings formed in a hadronic collision. We introduce the sources of the second type (secondary emitters), which imitate the appearance of the emitters of a new kind resulting from interaction (fusion) of the initial strings. The model enabled to describe effectively the influence of the string fusion effects on the strength both the n-n and the pT-n correlations.

It was found that in the region, where the secondary emitters start to produce, the calculation results predict the non-monotonic behaviour of the n-n and pT-n correlation coefficients with the growth of the mean number of initial strings, i.e. with the increase of the collision centrality. We show also that the increase of the event-by-event fluctuation in the number of primary strings leads to the change of the pT-n correlation sign from negative to positive. Similar behaviour of the pT-n correlation coefficient was observed experimentally in the lead-lead collisions at the top SPS energy [2]. One can try to search all these signatures of string collective phenomena in interactions of various nuclei at different energies varying the class of collision centrality and its width.

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SELF-SIMILARITY OF CUMULATIVE HADRON PRODUCTION IN pA COLLISIONS AT LOW AND HIGH p_T

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Abstract

Data on momentum spectra of charged hadrons produced in pA collisions at U70 and FNAL are analyzed in a framework of the z-scaling approach. Corresponding kinematical regions cover regions forbidden for the particle production in free nucleon-nucleon collisions at low and high p_T. This phenomenon is known as the cumulative particle production. Scaling function $\psi(z)$ expressed via the invariant cross section $Ed^3\sigma/dp^3$ and the average multiplicity density $dN_{ch}/d\eta(\sqrt{s},\eta)$ of charged particles is constructed. Results of the analysis are compared with data obtained by J.Cronin and D.Jaffe groups at FNAL and R.Suliaev group at IHEP for the noncumulative hadron production at high p_T. Universality of the shape of scaling function $\psi(z)$ is verified. Self-similarity of the hadron production in pA collisions over a wide kinematic range is confirmed.

EXPOSURES OF NUCLEAR TRACK EMULSION TO LIGHT RADIOACTIVE NUCLEI, NEUTRONS AND HEAVY IONS

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Nuclear track emulsion (NTE) stays to be a versatile and inexpensive technique for forefront researches. In JINR samples of reproduced NTE have been exposed to 1.2 A GeV ^{11}C nuclei, 7 A MeV ^{8}He nuclei, thermal and fast neutrons and 1.2 A MeV Kr and Xe ions. NTE has retained its position as a means for studying a nuclear clustering via relativistic fragmentation [1]. The Nuclotron allows one to expose NTE to light radioactive nuclei. Data on coherent dissociation of the nuclei ^{11}C in NTE are discussed. Using the ACCULINNA separator ^{8}He nuclei were implanted into NTE which allowed to observe a drift of ^{8}He atoms and to derive the distribution over decay energy $Q_{2\alpha}$ [2]. The established "tail"of large values $Q_{2\alpha}$ could allow one to examine a structure of the state ^{8}Be^{2+}. Correlations of α-particles ^{12}C$\rightarrow 3\alpha$ are studied in NTE exposed to 14.1 MeV neutrons of the apparatus DVIN [3]. Energy distributions $Q_{2\alpha}$ and $Q_{3\alpha}$ indicate on superposition of the ^{8}Be 0^+ and 2^+ states in the ^{12}C ground state at that ^{8}Be^{2+} is dominating. NTE enriched with boron is exposed to thermal neutrons at the reactor IBR-2 allow one to extend range calibration for the ^{7}Li nucleus using events $n + B \rightarrow Li + \alpha + \gamma$. Angular and energy correlations of the reaction products are studied. There is a prospect of an NTE application in physics of a ternary fission. It is necessary to perform range calibrations and to estimate of angular resolution for an available variety of heavy ions. NTE samples without light protection paper are exposed to ions ^{86}Kr^{+17} and ^{132}Xe^{+26} at the cyclotron IC-100. Ranges of Kr and Xe ions correspond to the primary energy value. Scatterings of ions degraded in NTE to 300 A keV with a visible recoil nucleus are measured. Progress of analysis of NTE exposure to a ^{252}Cf source will be presented. Number of events analyzed in these pilot studies is a small part of available statistics. NTE provides a basis for the application of automated microscopy and image recognition software, allowing one to rely on unprecedented statistics. Thus, a synergy of classical nuclear technique and modern technology can be achieved. The report is illustrated by macrophotographs of the discussed events.

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ENERGY DEPENDENCE OF THE $^{NAT}U(N,F)$, $^{NAT}U(N,\gamma)$ AND $CO(N,X)$ REACTION RATES IN THE VOLUME OF QUINTA SETUP IRRADIATED BY 1-4 AGeV DEUTERONS AND ^{12}C IONS

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The work is dedicated to experimental results of neutron generation obtaining in massive natural uranium target surrounded by the lead shielding by relativistic deuterons and ^{12}C ions with energies of 1-4 AGeV irradiation. The work was carried out at the Veksler and Baldin Laboratory of High Energy Physics of Joint institute for nuclear research, Dubna, Russia at NUCLOTRON accelerator. The spatial distributions of neutron capture $^{nat}U(n,\gamma)$ (^{239}Pu production), fission $^{nat}U(n,f)$ and $Co(n,x)$ reaction rates were obtained using activation technique. Spatial distributions of spectral indices $\bar{\sigma}^{238U}_{(n,\gamma)}/\bar{\sigma}^{238U}_{(n,f)}$, $\bar{\sigma}^{238U}_{(n,2n)}/\bar{\sigma}^{238U}_{(n,f)}$ and $\bar{\sigma}^{238U}_{(n,2n)}/\bar{\sigma}^{238U}_{(n,\gamma)}$ over the assembly were obtained. As well dependencies of incident deuteron energy of reaction rates $^{59}Co(n,x)\,^{48}V/^{59}Co\,(n,p)^{59}Fe$ and $^{59}Co(n,x)\,^{44}Sc/^{59}Co\,(n,p)^{59}Fe$ are shown. This experiment allows comparing all obtained results in dependence of particle type and its energy. The obtained results can be used to solve the problems of radioactive waste transmutation and power generation.

A PARTICLE EMISSION REGION SIZE IN MULTIPARTICLE PRODUCTION PROCESS

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In this paper we have obtained the formula which determines the particle emission region size r,

$$r = \frac{1}{\sqrt{n_c} \cdot m_p} = \frac{\lambda_c^p}{\sqrt{n_c}} = \frac{0.21\,fm}{\sqrt{n_c}};$$

Where the variable $n_c = \frac{E - \beta_a P_{II}}{m_p}$ is cumulative number, E and P_{II} are the energy and the longitudinal momentum of the secondary particle, m_p is the proton mass, λ_c^p is the Compton wavelength of proton, β_a is the velocity of the incident particle.

Corresponding distributions on the parameter r^2 are presented for the secondary negative pions and protons from $\pi^- C$ interactions at 40 GeV/c.

PERSPECTIVE STUDY OF CHARMONIUM AND EXOTICS WITH HIDDEN CHARM ABOVE $D\overline{D}$ THRESHOLD

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The spectroscopy of charmonium and exotics is discussed. It is a good testing tool for the theories of strong interactions, including: QCD in both the perturbative and non-perturbative regimes, LQCD, potential models and phenomenological models. For this purpose an elaborated analysis of the charmonium, charmed hybrids and tetraqurks spectra is given, and attempts to interpret recent experimental data in the above $D\overline{D}$ threshold region are considered. Experimental data from different collaborations (BES, BaBar, Belle, LHCb) are analyzed with special attention given to new states with hidden charm that were discovered recently. Some of these states can be interpreted as higher-lying charmonium states and tetraquarks with a hidden charm. It has been shown that charge/neutral tetraquarks must have their neutral/charged partners with mass values which differ by few MeV. This hypothesis coincides with that proposed by Maiani and Polosa. But much more data on different decay modes are needed before firmer conclusions can be made. These data can be derived directly from the experiments using a high quality antiproton beam with momentum up to 15 GeV/*c* and proton-proton collisions with momentum up to 20 GeV/*c*.

MEASUREMENTS OF FAST NEUTRON SPECTRUM IN QUINTA ASSEMBLY IRRADIATED WITH 2,4 AND 8 GEV DEUTERONS

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Experimental values of high energy neutron flux by application Yttrium-89 foils in QUINTA assembly, using 2, 4 and 8 GeV deuteron beams (Fig. 1) from the JINR Nuclotron (2012 E+T – RAW experiments) are presented. Evaluation of average high energy neutron fluxes for three energy ranges (11,5-20.8, 20,8-32.7, 32,7-100 MeV) using the determined three isotopes production of ^{88}Y ^{87}Y and ^{86}Y [1] are performed. The (n,xn) reaction rates of yttrium samples located inside the assembly were determined through gamma spectrometry. We stared to check values of cross section data for Y-89 neutron reactions (n,xn) experimentally.

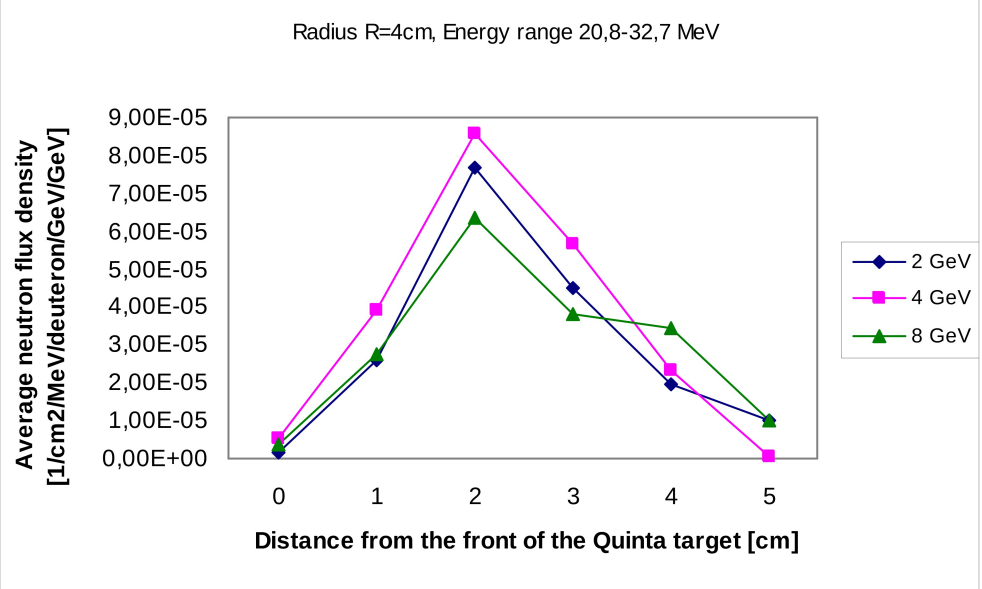

Fig. 1 Spatial average neutron flux distribution in the QUINTA assembly for the neutron energy range (20.8 – 32.7) MeV for the deuteron beam of 2, 4 and 8 GeV as the illustrative example.

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DETERMINATION OF HEAVY METAL SPALLATION REACTIONS CROSS SECTIONS AT 2, 2.94, 3.5 GeV DEUTERON BEAMS

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The ratios of the average plutonium-239 and neptunium-237 fission cross-sections to the average uranium-235 fission cross-section were determined experimentally. Experiments with U-assembly 'QUINTA' were carried out using the accelerator complex Nuclotron of the Veksler and Baldin Laboratory of High Energy Physics (VBHEP) of the Joint Institute for Nuclear Research (JINR) (Dubna, Russia). Experiments were conducted in the frame of the project E&T RAW. It is based on so called Relativistic Nuclear Technology (RNT) proposed recently [1] by one of the institutions (CPTP Atomenergomash, Moscow) participating in E&T RAW collaboration. The assembly was irradiated by deuterons and carbon ions with energies 2 GeV/A and 4 GeV/A. Comparison between experimental results and MCNPX calculations are presented. Accumulation and burning of plutonium, neptunium and others isotopes affect on the neutron balance of the assembly that attract an interest in such measurements.

STUDY OF CROSS-SECTIONS OF YTTRIUM (N,XN) THRESHOLD REACTIONS

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Currently the development of the nuclear systems is heading to systems with fast neutrons instead of thermal ones. Such systems are mainly fast reactors of generation IV family and accelerator driven systems. Unfortunately the possibilities of monitoring fast neutrons are limited. One of possible principles is to use activation detectors. It has shown up that yttrium is very good candidate to act as the activation detector of the fast neutrons. The advantages of yttrium are namely its (n,xn) threshold reactions and the fact that its only one naturally occurring isotope. To be possible to use yttrium as the activation detector it is necessary to know the cross-sections of the (n,xn) reactions sufficiently good. This condition is fulfilled only in case of the ^{89}Y(n,2n)^{88}Y reaction. For higher orders of reactions there are almost no experimental data.

For this reason a series of experiment were made using quasi mono-energetic neutron source based on the reaction of protons with ^{7}Li target at Nuclear Physics Institute of ASCR in Rez. Special attention was paid to the ^{89}Y(n,3n)^{87}Y reaction. In this case the nuclei are produced both in the ground state and in the isomeric state. The half-lifes are 79.8 hours for the ground state and 13.38 hours for the isomeric state. The isomeric state decays mainly through the gamma transition to the ground state. The beta decay of the isomeric state is within our accuracy negligible. The cross-sections of both cases of products were analyzed and compared with existing experimental data, calculated models and evaluated values.

COMPARISON OF FRACTAL ANALYSIS METHODS FOR FRACTAL AND RANDOM DATA SETS

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Properties of self-similarity and fractality in the processes of interactions of hadrons and nuclei at high energies are discussed. Different methods of fractal analysis (the box counting BC, p-adic coverage PaC, system of the equations of p-adic coverage $SePaC$ methods) are presented. The two-step procedure for PaC and $SePaC$ methods of fractal reconstruction is justified. The search procedure of optimal values of parameters for BC, PaC and $SePaC$ methods is developed. Comparison of the fractal analysis methods for fractal and random data sets is performed. The two-step procedure of fractal analysis for $SePaC$ method is shown to has advantages (fully event reconstruction and lowest impurity) before other ones.

NEW STATUS OF THE PROJECT η-NUCLEI AT THE NUCLOTRON

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In 2006-2010 a set of experimental data on the internal d-beam of the Nuclotron and two-arms time-of-flight setup has been produced. These data indicate the possible existence of η-mesic nuclei. The new project should provide a significant increase of the energy resolution of the upgraded setup, including through the inclusion of a magnetic spectrometer in the experimental installation and increase the time-of-flight base. We review status of the new project on the search of the η-mesic nuclei at the internal target of the Nuclotron, LHEP JINR.

DOUBLE PHOTOPRODUCTION OF NEUTRAL PIONS ON LIGHT NUCLEI

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Theoretical model of double neutral pion photoproduction on light nuclei p,d,^7Li,^{12}C is presented. Under the relativised isobar model of elementary process $\gamma N \to \pi\pi N$ [1] the final cross sections in coherent reactions are estimated on the parameter's dependence. As the result of inclusion all known possible contributions to elementary process we also evaluated the rescattering process $\pi\pi \to \pi\pi$ under the experimental data [2]. Our numerical efforts let us to propose that disagreement in experimental and theoretical cross sections differs with "missing" resonance problem known in literature on the double neutral pion photoproduction [3]. For this aim we evaluated the behavior of $\gamma + A \to \pi^0\pi^0 + A$ models as the function of mesonic masses and widths in intermediate states, it was also fitted meson vertex dependence.

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PHENOMENOLOGY AND SPACE-TIME PICTURE OF HADRONIZATION: PAST, PRESENT AND FUTURE

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At present, there has been expressive interest in the study of ultra-relativistic collisions of heavy nuclei. Such an interest stems from the possibility of production and study under laboratory conditions of the Quark Gluon Plasma (QGP, the new state of matter of QCD). In the dynamical evolution of relativistic heavy ions collisions they run through various states, from an initial high-nonequilibrium stage through a very hot stage of a new state of matter (QGP). Any observed signal necessarily represents a time-integral over all quite distinct physically states of nuclear matter. At the same time, in experiments with particles probing nuclei we can test interactions with nuclear matter in a well-known state. Although the density probed is smaller than density of QGP, the expected signals are large. It is believed that these experiments are complementary to heavy ion collision experiment. Atomic nuclei can be used as spatial analyzers of the hadronization process in semi-inclusive deep inelastic scattering. In a sense, the nucleus behaves as a very dense hydrogen bubble chamber.

In the process of nuclear collision the momentum transfer between the hadrons leads to the excitation of hadronic strings. Hadronization is the mechanism by which quarks and gluons produced the hadrons that are observed in the final state. This is an nonperturbative process, for which we have only models at present. Studying of the space-time evolution of hadronization is very important for correctly interpreting the signals of QGP formation (e.g., jet-quenching, etc.) in heavy ion collisions.

We developed a cascade model of multiproduction from Deeply Inelastic lepton-nucleus Scattering (DIS). On the phenomenological level, the model describes a Markov branching process of the evolution of parton's shower (up to hadronization) in the atomic nucleus. For the parton jet from lepton–nucleon interaction, we used the experimental data and the consept of Local Parton Hadron Duality of Ya.I. Azimov, Yu.L. Dokshitzer *et al.*

The formation zone phenomena (Landau-Pomeranchuk-Migdal) effect and cascading of soft particles was taken into account. The process of generation of particles was simulated by the Monte Carlo method. The creaned hadrons (pre-hadrons) travel inside the nuclear medium with a reduced scattering probability during their formation time. This process continues until all secondaries escape target nucleus. A part of the energy is spread through the nucleus to produce a fully-equilibrated nucleus which then decays statistically. The process of generation of particles is simulated by the Monte Carlo method.

The formation zone was extracted from comparison of calculations and data on neutrino-nuclei scattering. Our estimations of the formation time of hadrons are in agreement with probing the hadronic formation times with other projectiles (antiprotons, photons, *etc*). In conclusion, the formation time plays an important role in the dynamics of nuclear reactions, e.g. heavy ion collisions, proton and pion induced reactions as well as photon and electron induced reactions on nuclei.

Experiments using relativistic heavy ions are aimed to produce a system at very high densities and connected with that very high temperatures. In their dynamical evolution they run through various states, from an initial high-nonequilibrium stage through a very hot stage of a new state of matter (QGP). Any observed signal necessarily represents a time-integral over all these physically quite distinct states of nuclear matter. On the contrary, in experiments with microscopic probes on cold nuclei one tests interactions with nuclear matter in a well-known state, close to cold equilibrium. Even though the density probed is always smaller than the nuclear saturation density, the expected signals are as large as those from ultrarelativistic heavy-ion collisions.

In a high energy collision between two hadrons or a photon and a hadron it takes a finite amount of time for the reaction products to evolve to physical particles. During the collision process some momentum transfer between the hadrons or some hard scattering between two of the hadrons constituents leads to the excitation of hadronic strings. The time that is needed for the creation and fission of these strings as well as for the hadronization of the string fragments cannot be calculated within perturbative QCD because the hadronization process involves small momentum transfers of typically only a few hundred MeV. One can perform an estimate of the formation time ?f in the rest frame of the hadron. It should be of the order of the time that the quark-antiquark (quark-diquark) pair needs to reach a separation, that is of the size of the produced hadron (rh ? 0.6 ? 0.8 fm): During their evolution to physical hadrons the reaction products will react with reduced cross sections. This is motivated by means of color transparency: the strings and the substrings created during the fragmentation are in a color singlet state and therefore react with a cross section that increases with their transverse size. As a consequence the produced hadrons travel inside the nuclear medium with a reduced scattering probability during their formation time. Hence the formation time plays an important role in the dynamics of nuclear reactions, e.g. heavy ion collisions, proton and pion induced reactions as well as photon and electron induced reactions on nuclei. The latter two are of special interest because they are less complex than heavy ion collisions and, in contrast to hadron induced reactions, the primary reaction does in general not only take place at the surface of the nucleus but also at larger densities. Experiments at TJNAF and DESY, for example, deal with exclusive and semi-inclusive meson photo- and electroproduction at high energies. Large photon energies E? are of special interest because

It is also emphasize that final state interactions can have a famous effect on observables and thus have to be intended as part of the theory. This is demonstrated with examples from neutrino-nucleus deep inelastic interactions. In the end, the possibility to obtain hadron formation times in high-energy neutrino-induced reactions is demonstrated.

Furthermore, the quantitative information can provide enlightenments and references for the study of quark-gluon plasma and its space-time evolution in ultra-relativistic heavy-ion collisions.

SIMULATIONS OF MPD STRAW END-CAP TRACKER

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A response of the MPD Straw End-Cap Tracker has been estimated employing FAIRROOT, GEANT3, GARFIELD and the hit simulation and reconstruction programs. The MC simulations allowed us to study the following detector characteristics: the occupancy, the charge clusters distributions and energy losses, drift properties (electron and ion drift times, electron attachment probabilities, drift and lavina regions), gas gain, anode signals, the integrated anode charges. The calibration method [1], [2], [3] has been used to estimate hit distance of closest approach (DCA) coordinates which are necessary for the track reconstruction. The DCA coordinate resolution varies from 100 μm to 300 μm depending on the radial distance from anode wire. Our results are found compatible with the results from other HEP experiments employing straw tube detectors, e.g. PANDA [1] and ATLAS [2], [3].

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NEW Si VERTEX DETECTOR FOR NA61/SHINE

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Measurements with the NA61/SHINE experiment [1] at the CERN SPS of hadrons containing charm quarks could be important in investigations of the initial stage of nucleus-nucleus collision at relativistic energies. The first feasibility studies [2], [3],[4] of direct open charm measurements in central Pb-Pb collisions at SPS energies has proved the possibility of such an experiment and established the requirements for the design of the new Vertex Detector (VD) for the NA61 installation. This new, high precision VD should be capable of providing an accuracy of particle tracking to the vertex on the level of a few microns. The VD is also required to have extremely low material budget (of the order of 0.3 % Xo), a high radiation tolerance and rather high speed. These requirements are to be met using coordinate sensitive Si-sensor chips in CMOS technology. In this report we present the general design of a new VD for NA61/SHINE. Some practical solutions to meet the requirements for this VD are proposed and demonstrated based on the experience obtained and proven earlier [5].

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CONSTRAINTS ON STRING PERCOLATION MODEL FROM ANOMALOUS CENTRALITY EVOLUTION DATA IN Au-Au COLLISIONS AT $\sqrt{s_{NN}}$ = 62 AND 200 GeV

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The anomalous centrality evolution of two-particle angular correlations was observed for the first time by STAR collaboration at RHIC in Au+Au collisions at $\sqrt{(}sNN) = 62$ and 200 GeV [1, 2]. It was found that this evolution occurs at a specific Au-Au centrality, common to both energies, indicating on the existence of the energy-dependent centrality point where some sudden changes in the correlation pattern are observed. Namely, at the given collision centrality the onset is observed of specific long-range correlation structures that are found to be extended in pseudorapidity and localized in azimuth opposite regions at $\varphi = 0$ and π (so-called near- and backside ridges). In the present work we continue with study [3] based on application of the pioneering hypothesis of interacting color flux tubes (strings) [4] and of the parton string percolation model as a natural explanation of the conditions of the given onset. We assume that some critical energy density is reached and this might be a result of the critical string density achieved in the model of string percolation at the given collision centrality. Numerical constraints on the percolation model are obtained and qualitative explanations are discussed in the framework of simplified model of interacting color flux tubes.

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DECAY OF HADRONIC RESONANCES IN THE MAGNETIC FIELD

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It will be discussed, how much the strong magnetic field created in heavy ion collisions can influence decay of baryonic (Λ^*, Ξ^*) and mesonic (D^*, K^*) resonant states. For this purpose Landau energy levels of charged decay products in the magnetic field will be compared to the energy (mass) of decaying hadronic resonances. We shall take into account also the interaction of the magnetic moments of hadron resonances with the magnetic field. Our method is similar to calculation used in [1] for $\rho(770)$ meson decays.

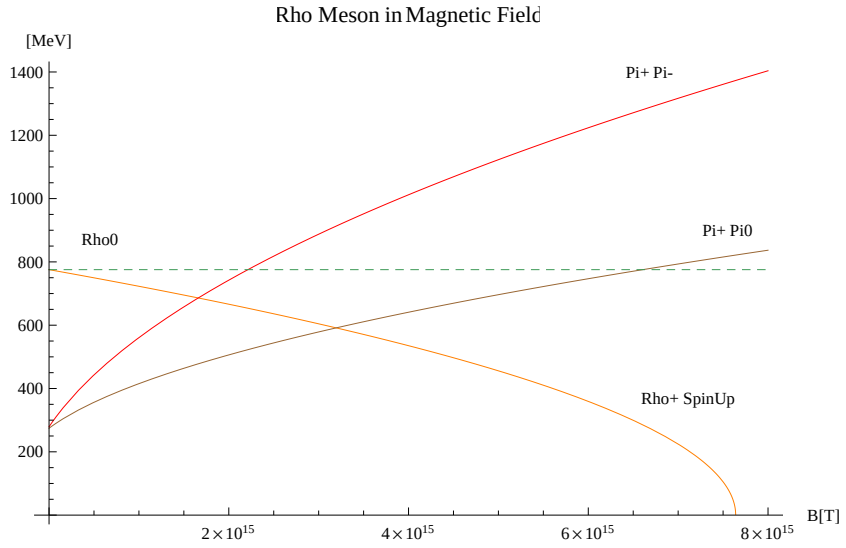

Figure 1: Energy of $\rho(770)$ meson and the lowest Landau levels of $\pi^+\pi^-$ and $\pi^+\pi^0$.

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DYNAMICS OF INTERACTIONS OF ANTI-PROTONS AND ANTI-NUCLEI WITH NUCLEI IN GEANT4

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Various processes take place in antiproton-proton interactions which are caused by the creation and fragmentation of quark-gluon strings. The cross sections of these processes are not well determined. We undertook an attempt to estimate them in the framework of Reggeon theory, but we were not satisfied by the results. Thus, we present a new attempt to determine the cross sections from an analysis of a wide set of experimental data. Some detail of the analysis will be given. The developed approach allows one to describe the main regularities of antiproton-proton interactions.

Generalizing the approach for antiproton-nucleus and antinucleus-nucleus interactions requires a knowledge of total and inelastic cross sections of these processes. The cross sections are calculated in the Glauber approximation. Good results [1] are obtained for all experimentally known cross sections.

Usually, the asymptotic Abramovsky-Gribov-Kancheli (AGK) cutting rules are applied for a determination of the multiplicity of produced strings. We propose finite energy corrections to the AGK rules for an extension of the model to the low energy domain. As a result, we describe antiproton-nucleus interactions starting from low energies ($E > 50$ MeV) up to 1000 GeV. We also reproduce known experimental data on antideuteron interactions with nuclei.

So, we have a unified model of antiproton-proton, antiproton-nucleus and light antinucleus-nucleus interactions [2]. The model reproduces general properties of the interactions. The model is implemented in the Geant4 toolkit and can be accessed using the FTF_BERT PhysicsList.

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MESON MASS SPECTRUM AND THE FERMI COUPLING IN THE COVARIANT CONFINED QUARK MODEL

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A new insight into the problem of hadron mass spectrum is provided in the framework of the covariant confined quark model. Along the *compositeness condition* enabling the elimination of the renormalization constant of the elementary hadron wave function in the Yukawa-type theory, we employ another equation which relates the meson mass function to the Fermi coupling of the relevant four-fermion interaction. Both equations guarantee that the Yukawa-type theory is equivalent to the Fermi-type theory, thereby providing an interpretation of the meson field as the bound state of constituent fermions (quarks). We evaluate the Fermi coupling G as a function of the meson mass M and vary the values of the mass so that to obtain a smooth behavior of $G(M)$. The conventional (pseudoscalar and vector) meson mass spectrum estimated in this manner is found to be in good agreement with the latest experimental data in a wide range of mass scale. We also compare the behavior of the obtained $G(M)$ with the strong QCD coupling α_s calculated in a QCD-inspired approach.

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THE STRUCTURE OF TWO LOWEST MASS SCALAR MESON MULTIPLETS DERIVED BY USING A KIND OF THE "INVERSE PROBLEM" APPROACH

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The flavour $SU(3)$-symmetry basis used to diagonalize the combined $q\bar{q}$- and $q^2\bar{q}^2$ - quark multiplets mass-matrix. The particular $q^2 - to - q^4$ - transition-mass term is defined to be twice less than in the earlier published works [1], and the mass of the strange κ-meson and the mainly isoscalar SU(3)-octet σ meson turn out to be $m(\kappa) \simeq 850MeV$ and $m(\sigma) \simeq 614MeV$. The very small mixture of the $f_0(1720)$-meson with lower mass isoscalar meson states is in accord with the earlier made statement [2] about its dominant glueball nature.

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MEASUREMENT OF THE CHARGE EXCHANGE *np→pn* REACTION BY MEANS OF THE DEUTERON BEAM

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The ratio of the differential cross section of the charge exchange reaction of the deuteron to that of the nucleon, at small transferred momenta, has been discussed in order to estimate the spin-dependent part of the *np → pn* charge exchange amplitude. An estimation of the spin-dependent part of the *np → pn* charge exchange amplitude was made on the basis of *dp → (pp)n* data, taken at 1.75 GeV/c per nucleon using the STRELA setup at the Nuclotron accelerator. The *np → pn* amplitude turned out to be predominantly spin-dependent.

PION POLE AND TRANSVERSITY EFFECTS IN HARD EXCLUSIVE MESON LEPTOPRODUCTION

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We investigate exclusive electroproduction of vector and pseudoscalar mesons at large photon virtuality Q^2. These reactions where analyzed within the handbag approach where amplitudes factorize into hard subprocesses and generalized parton distributions (GPDs) which contains information about the hadron structure.

The essential role of transversity effects were found in pseudoscalar and light vector meson leptoproduction. These contributions are determined by twist-3 effects and mainly essential at not very high Q^2. The transversity GPDs lead to large transverse cross sections for most reactions with the exception of π^+ and η' production [1]. The spin asymmetries in vector meson production which are sensitive to transversity were studied too.

The role of pion was analysed in vector meson leptoproduction. It was shown that pion pole contribution is very important in ω production [2]. Its contribution to ρ^0 channel is smaller. We consider spin observables in ρ^0 and ω leptoproduction reactions. Our results on spin asymmetries and spin density matrix elements in light meson leptoproduction were found to be in good agreement with CLAS, HERMES and COMPASS data.

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DETERMINATION OF THE RATIOS OF THE AVERAGE ^{239}Pu AND ^{237}Np FISSION CROSS-SECTIONS TO THE AVERAGE ^{235}U FISSION CROSS-SECTION IN QUINTA NEUTRON FIELD

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The ratios of the average ^{239}Pu and ^{237}Np fission cross-sections to the average ^{235}U fission cross-section were determined experimentally. Experiments with U-assembly "QUINTA" were carried out using the accelerator complex "Nuclotron" of the Veksler and Baldin Laboratory of High Energy Physics (VBHEP) of the Joint Institute for Nuclear Research (JINR) (Dubna, Russia). Experiments were conducted in the frame of the project "E&T RAW". It is based on so called Relativistic Nuclear Technology (RNT) proposed recently [1] by one of the institutions (CPTP "Atomenergomash", Moscow) participating in E&T RAW" collaboration. The assembly was irradiated by deuterons and carbon ions with energies 2 GeV/A and 4 GeV/A. Comparison between experimental results and MCNPX calculations are presented. Accumulation and burning of plutonium, neptunium and others isotopes affect on the neutron balance of the assembly that attract an interest in such measurements.

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A MONTE CARLO STUDY OF THE STRANGE PARTICLE PRODUCTION AT NICA/MPD

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One of the main tasks of the NICA/MPD physics program is a study of the strangeness production in nuclear collisions. The MPD detector performance will be presented for measurements of Λ, Ξ^-, Ω^- hyperons and their antiparticles $\bar{\Lambda}$, $\bar{\Xi}^+$, $\bar{\Omega}^+$ as well as hypernuclei ${}^{3}_{\Lambda}\mathrm{H}$ in central Au+Au collisions at NICA energy region.

DI-PION PRODUCTION IN NP-INTERACTION AT INTERMEDIATE ENERGIES

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The reactions $np \to np\pi^+\pi^-$, $np \to pp\pi^-\pi^0$ and $np \to d\pi^+\pi^-$ were studied at the various momenta of incident neutrons. It was shown that the characteristics of the reactions at the momenta above 3 GeV/c could be described by the model of reggeized π exchange (OPER) [1, 2, 3]. At the momenta below 3 GeV/c, it was necessary to use additionally the mechanism of one baryon exchange (OBE) [4].

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ELECTRODISINTEGRATION OF BOUND SYSTEM IN THE MINKOWSKI SPACE BETHE-SALPETER APPROACH

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We have recently developed a new method [1] to compute the solutions of the Bether-Salpeter (BS) equation, directly in Minkowski space. It is based on the appropriate treatment of the propagtors singularities in the BS equation, as well as the kernel singularities and those of the BS amplitude itself. We considered a system of spinless particles interacting by one-boson exchange. This method provided us the bound state and the off-shell scattering BS amplitudes and, as a by-product, the elastic and inelastic phase shifts. Using the bound state amplitude found by via Nakanishi representation we previously calculated the elastic e.m. form factor [2]. Having at our disposal the full – bound and scattering – solutions, the bound $\to$ scattering state transition e.m. form factor was obtained in [3]. The final state interaction was taken into account by our Minkowski space solution for the off-shell BS amplitude.

We continue this study by presenting in this contribution the variation of the electrodisintegration amplitude of a bound system as a function of the momentum transfer for a few values of final state energy, varying both variables in relativistic domain. This amplitude includes the plane wave and the final state interaction. An emphasis is done to verifying the gauge invariance which should manifest itself in the conservation of the transition e.m. current $J \cdot q = 0$. We check that the contributions of the plane wave and the final state interaction to the quantity $J \cdot q$ cancel each other that ensures the current conservation. However, this cancellation occurs only if the initial bound state BS amplitude, the final scattering state one and the operator of e.m. current are consistent with each other. Otherwise the current J is not conserved and it does not provide the correct electrodisintegration amplitude.

These results open way to theoretically self-consistent calculations using the kernels motivated by field theory, in particular, for computing the deuteron electrodisintegration. So far, these calculations were done with the separable kernel [4], or in the framework of so-called static approximation.

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MEASUREMENTS OF NP-237 INCINERATION IN ADS SETUP QUINTA

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Np-237 samples were irradiated in spallation neutrons produced in ADS setup QUINTA. Three experiments were carried on. The accelerator beam consisted of deuteron ions of energy 2, 4 and 8 GeV respectively. The method was based on gamma spectra measurements. During analysis of the spectra several fission products and one actinide were identified. Fission product activities gave the number of fissions. The actinide (Np-238), a result of neutron capture by Np-237 gave the number of captures.

STUDY OF CLUSTERS AND HYPERNUCLEI PRODUCTION WITH NICA/MPD AND BM@N EXPERIMENTS

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Heavy-ion collisions provide the unique possibility to create and investigate hot and dense matter in the laboratory. At the initial stage of the reaction a QGP is formed, while the final stage is driven by the hadronization process and the formation of clusters. The capture of the produced hyperons by clusters of nucleons leads to the hypernuclei formation which is a very rare process at strangeness threshold energies. In this respect it is important to have the robust modeling of such processes in order to study the detector replica and to have the possibility to optimize the experimental setup for the best efficiency.

We report on the first results on the dynamical modeling of cluster formation with the combined PHSD+SACA (Parton-Hadron-Strings dynamics + Simulated Annealing Clusterization Algorithm) model at Nuclotron and NICA energies. The clusters selection in SACA is realised by a simulated annealing procedure to obtain the most bound configuration of fragments and nucleons.

Based on present predictions of the combined model we study the possibility to detect such clusters and hypernuclei in the BM@N and MPD/NICA detectors.

HADRONIC RESONANCE PRODUCTION WITH ALICE AT THE LHC

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Resonance production plays an important role both in elementary and in heavy-ion collisions. In pp collisions, it provides a reference for nuclear collisions and also data for tuning event generators inspired by Quantum Chromodynamics. In heavy-ion collisions, the in-medium effects related to the high density and/or high temperature of the medium can modify the properties of short-lived resonances such as their masses, widths and spectral shapes. Moreover, due to short life time the regeneration and rescattering effects become important and can be used to estimate the timescale between chemical and kinetic freeze-out. In this talk we present results on short-lived hadronic resonances obtained by the ALICE experiment at LHC energies. Transverse momentum spectra, yields, ratio to stable particles, nuclear modification factors and comparison with model predictions will be discussed. The ALICE results will be compared with data obtained at lower energies.

RADIATIVE CORRECTIONS TO POLARIZATION OBSERVABLES OF ELASTIC ELECTRON-PROTON SCATTERING

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We consider radiative corrections to polarization observables in elastic electron-proton scattering, in particular, for the polarization transfer measurements of the proton form factor ratio $R = \mu G_E/G_M$. The corrections are of two types: two-photon exchange (TPE) and bremsstrahlung (BS). TPE corrections are calculated within dispersion approach taking into account elastic and inelastic parts. The elastic part includes pure nucleon intermediate state only. The inelastic part is saturated by πN intermediate states [1]. The advantages of this approach with respect to considering contributions of resonances are (i) automatically having correct resonance width, (ii) automatically having correct resonance shape, (iii) including not only resonances but background as well. Among different πN states we concentrate on the P_{33} channel (with quantum numbers of $\Delta(1232)$ resonance).

BS corrections were calculated assuming small missing energy or missing mass cut-off [2]. We show that such correction can be represented in a model-independent form, with both electron and proton radiation taken into account. Numerical calculations show that the contribution of the proton radiation is not negligible. Overall, at high Q^2 and energies the total correction to R grows, but is dominated by TPE. At low energies both TPE and BS may be significant; the latter amounts to ~ 0.01 for some reasonable cut-off choices.

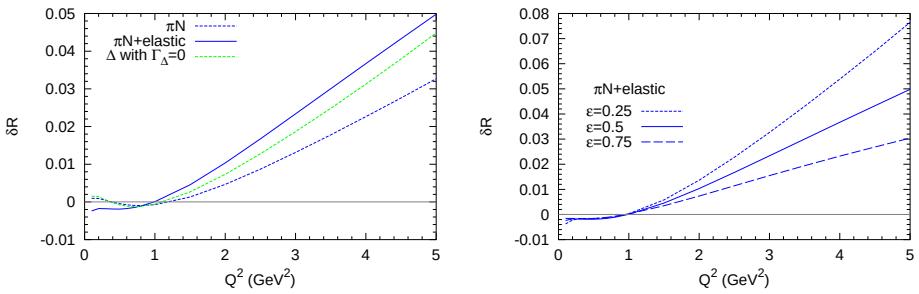

Figure 2: The TPE correction to the proton form factor ratio $R = \mu G_E/G_M$, as measured in polarization experiments, various contributions at fixed $\varepsilon = 0.5$ (left) and total (πN+elastic) at different values of ε (right).

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ANOMALOUS SOFT PHOTONS AT NUCLOTRON NUCLEAR BEAMS

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On behalf of SVD Collaboration

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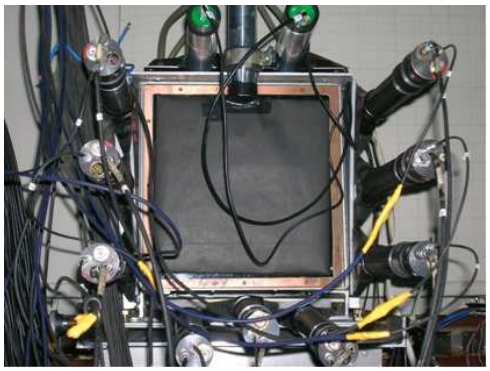
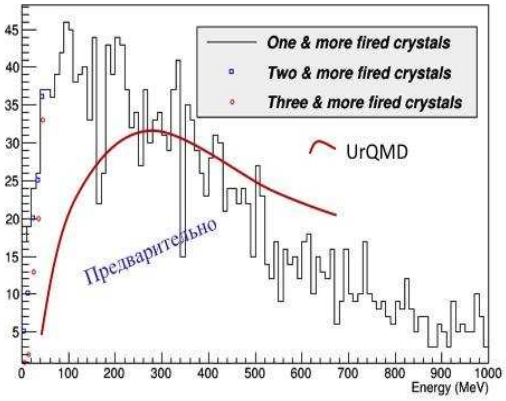
The collective phenomenon "the excess of soft photon yield" has been discovered in bubble chamber experiments and confirmed at modern setups in hadron and nuclear interactions, and also in hadron jets in e^+e^- annihilation. Soft photons have transverse moment less, than 60 MeV/c. Photons interact with matter weakly, so they keep information about medium from which they fly, and they are probes [1].

Collaboration SVD manufactured a soft photon electromagnetic calorimeter - SPEC (Fig. 1) allowed registering photons, from several MeV [2]. First methodical measurements on an accelerator U-70 have been carried out. Study of a soft photon yield has been begun in nuclear interactions at 3.5 GeV/nucl at Nuclotron (Fig. 2). It is planned to investigate the dependence of their yield on multiplicity of charged, neutrals and total multiplicity in the high multiplicity region. Such research is unique and allows approaching closer to understanding of a physical picture of soft photon formation and the nature of hadronization.



Soft photon electromagnetic calorimeter



Energy release in SPEC with preshower (deuterium beam and carbon target)

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PRODUCTION OF (ANTI)DEUTERONS IN HEAVY-ION COLLISIONS AT SPS ENERGIES

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Anti-deuteron and deuteron production has been studied in central Pb+Pb collisions at 158A GeV by the NA49 experiment (CERN SPS). Recent experimental data on spectra and yields will be reported and compared to model predictions.

MULTI-STRANGENESS IN HEAVY-ION COLLISIONS

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We discuss the strangeness production in heavy-ion collisions at SIS-FAIR-NICA energies and the role of doubly and triply strange baryons for testing the strangeness balance in a collision event. The minimal statistical model is applied, in which the total strangeness yield is fixed by the observed K^+ multiplicity. Exact strangeness conservation in each collision event is explicitly preserved. This implies for instance that Ξ baryons can be released only in events where two or more kaons are produced. We show how this approach can work for SIS energies and in the SPS energy range. The influence of in-medium effects and centrality bias on the strange particle production is discussed. The puzzling enhancement of Ξ and ϕ yields is discussed and arguments in favor of their production in direct reactions are given. Various mechanisms for Ξ and ϕ productions are reviewed.

45 YEARS OF "BALDIN AUTUMN"

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How it was begun. Before the Standard Model arose in the elementary particle theory the regular Markov-Baldin seminar appeared in Lebedev Physical Institute in Moscow. At the same time academician M.A.Markov and professor A.M.Baldin worked in JINR in Dubna. They led the experimentators groups in LPI and JINR, but they were very interested in theoretical questions as well. M.A.Markov was also occupied with philosophical problems of theoretical physics. International Seminar "Vector mesons and electromagnetic interactions", which took place under A.M.Baldin supervision in August 1969 in Dubna, demonstrated many new idears and approaches in theoretical and experimental physics of elementary particles. Then this field of knowledge was in deep crisis. But idears and experimental results represented for consideration of August Seminar got development and influenced on overcoming of the crisis.

The main role in this process played the gauge field theory which generated Standard Model. Now the question under discussion is: how can gravity be joined with Standard Model? Some decisions are recommended by supersymmetric models. But all supersymmetric models have not any experimental confirmation. On the other hand, already in 1969 in my talk at the seminar "Vector mesons and electromagnetic interactions" the method of unified approach to all interactions of elementary particles including Einstein gravity was proposed. As it is known Einstein theory of gravity (including Newtonian that) corresponds to all experimental data and is the theory of real physical field. All non-Einsteinian theories have not any experimental confirmations. In my talk Einsteinian General Relativity was considered the specific case of the gauge theory, when the gauge field is given by the symmetrical tensor of rank two and the symmetry group of the theory is local translation group. Distinctive feature of my theory - its classical formulation. The passage from classical theory to quantum that can be fulfiled by different ways. This problem is not completely investigated. It would be interesting to know how to obtain the relations of Standard Model in some geometrical form? Then the question about mass of Higgs boson could become more clear.

ACCELERATOR SYSTEMS FOR THE PRODUCTION OF MEDICAL ISOTOPES

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The irradiation of enriched (Oxygen-18) water by a proton beam in isochronous cyclotrons is a standard approach in the radiopharmaceutical industry for producing medical isotopes used in Positron Emission Tomography (PET). Increasing the production efficiency of Fluorine-18 (F-18) is critical for cyclotrons. The novel concept of accelerator systems based on post target acceleration of the proton beam for the additional irradiation of O-18 water targets is considered in this presentation. The main advantage of this concept is to maximize the efficiency of the proton beam for nuclear reactions resulting in increased efficiency and production (yield) of the F-18. The physical analysis of this system is provided. The comparison of this proposed system with the standard single target system is discussed.

ON CONSTRUCTION METHODS OF THE STRONG GRAVITATION THEORY

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We suggested considering "black holes" as hadrons with very large baryonic charges. It allows simulating similar objects in laboratory conditions (at high energy accelerators). Naturally, that we connect the use necessity of the quantum chromodynamics in the cosmology with the chance of the processes explanation whichs go in quasars and nuclei of Seyfert galaxies with the very large energy release. The Einstein theory cannot apply for this as in it the substantial object – the space–time torsion does not attend by the gravitation geometrization (the space–time torsion is the locally diffeomorphic one to the corresponding structural tensor field of the Lie local loop characterizing the symmetry of the quantum system). What is more, in the Hawking process of the "black holes" quantum evaporation is violated the conservation low of the baryonic charge, accumulated the massive collapsing star. If we shall apply this process for the description to two–photon decay of pseudoscalar neutral mesons (this low takes place at this point), then we receive a discrepancy with experimental data (instead the increase the particles lifetime is reducing with the growth of their masses). At present veritable elementary observable particles are considered charged leptons. We shell consider electrons and positrons as excited states of "sterile" neutrinos and antineutrinos [1], whichs are in the ground state under the temperature $T_\circ$ (the temperature of the cosmic microwave background may be its estimation) and the Fermi energy ε_F (the open resonance ($126GeV$) at LHC may be its estimation) in the boundary layer of Fermi sphere. The stability condition for the electron is written as

$$n\alpha T_\circ \varepsilon_F^{n-1} \approx m^n \tag{1}$$

($m_e \approx 0.5 \cdot 10^{-3}GeV$ is the electron mass, α is the fine structure constant, $n = 3$; we shall use the system of units $h/(2\pi) = c = 1$, where h is the Planck constant and c is the velocity of light). Here we took into account the Lie algebra dimension of Lie group $SU(2)$, which characterizes the properties of the lepton interior space, and also the equality of the pressure and the temperature for the electron and "sterile" neutrinos. The crude estimation shows ($\alpha \sim 10^{-2}$, $T_\circ \sim 10^{-13}GeV$, $\varepsilon \sim 10^2GeV$), that the relationship (1) is satisfied. If we shell consider hadrons, then it need take into account, that the properties of their interior space (in specifically, for the stable proton ($m \approx 1GeV$)) are characterized by group $SU(3)$ (the space dimension n is equal to 8). What is more, taking account of the above and considering so named "black holes", lied in nuclei of "normal" galactics, we can use the relationship (1) as the stability condition of theirs for $n \geq 8$.

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QUARTET OF TAU-LEPTONS AND POSSIBILITY OF THEIR OSCILLATIONS

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Early we found three types of equations for unstable leptons. Two of them are connected with the unstable charged leptons ($\mu^{\pm}$, $\tau^{\pm}$), the third is connected with a massive unstable neutrino. Analysis of tau lepton group (further group Δ_3) points to existence of doubles to $\tau^{\pm}$-leptons, that is $(\tau^*)^{\pm}$-leptons. Together they form a quartet state, or a multiplet. Existence of τ and τ^* is connected with that the group Δ_3 has two nonequivalent irreducible representations with dimension equal to four. Each of two nonequivalent representations describes a particle and antiparticle like Dirac's equation. Particles from different nonequivalent representations are not identical. Their quantum numbers coincide not completely. Therefore in this case it is possible to observe three various wave phenomena. Identical particles from the same nonequivalent representation can interfere. Particle and antiparticle from the same nonequivalent representations can annihilate. The leptons from different nonequivalent representations of the same quartet can oscillate.

POSSIBLE OBSERVATION OF PHASE TRANSITIONS IN N-N SYSTEMS AT JINR SYNCHROPHASOTRON

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A simple condition of deep cooling for observation of phase transitions in compressed few-nucleon systems was recently proposed in [1, 2]. Here we have checked it up using experimental data obtained in the first physical experiment with accelerated nuclei at JINR Synchrophasotron [3]. This study was inspired by a remark made by authors of [3] that one of peaks in an observed double differential cross-section may arise due to an "excited state of deuterium nucleus", although some other suggestions were also put forward. We have established that one of the peaks in the region mentioned in [3] corresponds to the dibaryon reported not long ago by WASA-at-COSY Collaboration. Another peak in the region may be explained, most likely, by excitation of several baryon resonances. This possibility is mentioned in [3] too.

Even a more amazing fact has been established in a kinematical regions which were considered till now as contributions of elastic deuteron-deuteron and nucleon(inside deuteron)-deuteron scattering. More careful calculations have shown that it is not the case. Trying to understand the nature of these peaks we looked over many dibaryons reported by different experimental groups and found that they may be excellently explained in terms of dibaryons with equidistant spectrum observed by Yu.A. Troyan [4, 5]. In our opinion, the most natural explanation of these dibaryons may be given on basis of generalized coherent states discovered by A. Perelomov [6], which are based on $SU(1,1)$ group. It is a purely nonperturbative effect described by Bogoliubov's transformation which produces a pion state beyond the range of the Fock space. These light dibaryons may be an experimental evidence for the pion Bose-Einstein condensate appearance in compressed and cooled nucleon systems. It should be also noted that this state of pion field has a mathematical and physical prototype in quantum optics, known there as the squeezed vacuum.

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CUT MELLIN MOMENTS APPROACH AND GENERALIZED DGLAP EQUATIONS

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Recent results on the generalization of DGLAP evolution equations within cut Mellin moments (CMM) approach are presented. The generalized CMM 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. The similar generalized evolution equation, with correspondingly modified coefficient functions, can be obtained also for structure functions. We present classes of CMM and corresponding them evolution kernels. We give an example of application of the CMM approach to analysis of the experimental data on the Bjorken sum rule. Using appropriate classes of CMM for the available experimental kinematic range enables enhancement of x-region with smaller uncertainties in the analysis.

CMM approach is a novel tool providing a rich variety of further possible ways to test QCD.

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LONG-RANGE CORRELATION STUDIES AT THE SPS ENERGIES IN MC MODEL WITH STRING FUSION

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Studies of the collisions of various hadrons and nuclei at different centrality and energy enable to explore the phase diagram of the strongly interacting matter over a wide range of temperature and baryon density in search of the critical point. Experimental exploration of the QCD phase diagram is a part of physical program of the NA61 experiment at the SPS and future detectors at FAIR and NICA. The studies of long-range correlations between variables from different rapidity windows, as a tool, sensitive to the observation of the critical point, are included in the research program of the experiment NA61 [1].

The theoretical modelling of the evolution of a heavy-ion collision with the calculation of observables in the conditions, close to the experimental ones, is required for the correct interpretation of experimental findings. In the present work, a Monte Carlo model of proton-proton, proton-nucleus, and nucleus-nucleus collisions [2, 3], is applied to heavy and light ion collisions at the cms energy range from a few up to several hundred GeV per nucleon. The model describes the proton-nucleus and nucleus-nucleus collisions at the partonic level without using Glauber model of nuclear collisions takes into account the effects of string fusion [4], which can be considered as an alternative to relativistic hydrodynamics way of describing collective effects in heavy-ion collisions. The implementing of both the string fusion and the finite rapidity length of strings allows to consider the particle production at non-zero baryochemical potential. We calculated the long-range correlation functions and correlation coefficients between multiplicities and transverse momentum at several energies for different colliding systems and obtained predictions for the experiment.

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LIGHT IONS IN CARBON FRAGMENTATION AT 0.3-2.0 GeV/n: COMPARISON WITH THE MODELS OF ION-ION INTERACTIONS

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Momentum distributions of hydrogen and helium isotopes from ^{12}C fragmentation at 3.5^o were measured in FRAGM experiment at ITEP TWA heavy ion accelerator on Be target. At energies 0.3, 0.6, 0.95 and 2.0 GeV/nucleon the momentum spectra of fragments span the region of fragmentation peak as well as the cumulative region. The differential cross sections cover 6 orders of its magnitude. The spectra were compared to the predictions of four ion-ion interaction models: LAQGSM03.03, SHIELD-HIT, QMD and BC. The data were also analyzed in the framework of thermodynamic approach where temperatures of nuclear matter in fragmentation and cumulative regions were obtained.

MEASUREMENT OF THE QUASI FREE $np \to np\pi^+\pi^-$ AND $np \to pp\pi^-\pi^0$ REACTIONS AT 1.25 GeV WITH HADES

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We present the results of two-pion production in tagged quasi-free np collisions at a proton incident beam energy of 1.25 GeV measured with the High-Acceptance Di-Electron Spectrometer (HADES) installed at GSI. The specific acceptance of HADES allowed for the first time to obtain high-precision data on $\pi^+\pi^-$ and $\pi^-\pi^0$ production in np collisions in a region corresponding to large transverse momenta of the secondary particles. The obtained differential cross section data provide strong constraints on the production mechanisms and on the various baryon resonance contributions ($\Delta\Delta$, $N(1440)$, $N(1520)$, $\Delta(1600)$). The invariant mass and angular distributions from the $np \to np\pi^+\pi^-$ and $np \to pp\pi^-\pi^0$ reactions are compared with different theoretical model predictions.

INVESTIGATION OF THE LIGHT NUCLEI SPIN STRUCTURE FROM HADRONIC CHANNELS AT NUCLOTRON

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The wide experimental program devoted to the investigation of the spin structure of light nuclei using internal and extracted deuteron beam at Nuclotron(JINR, Dubna) is discussed. Recent data on the deuteron analyzing powers in $dp-$ elastic scattering obtained at Nuclotron demonstrate strong deviation from the relativistic multiple scattering model predictions at large scattering angle in the cms. The preliminary results on the study $dp-$nonmesonic breakup at $150 - 250$ MeV/nucleon and data on the energy dependence in $dp-$ elastic scattering up to 1 GeV obtained at internal target station at Nuclotron are reported.

INVESTIGATION OF AVALANCHE PHOTO DETECTORS IN NPI REZ IN FRAME OF COLLABORATION WORK WITH JINR IN 2014

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For calorimetry projects of CBM at FAIR Darmstadt and B&M in JINR, modern avalanche photo detectors (APDs) with high gain known as SiPM, MPPC, G-APD are excellent candidates. In collaboration with group from LHE/JINR, we start project aimed on readout optimization, APD selection, radiation hardness and data analysis to understand behaviour of APD under normal conditions and in radiation environment. We present results of investigation of several types of APDs produced by Zecotek, KETEK, Hamamatsu as well as results of investigation of new pre-amplifier with variable gain as DAQ prototype based on Cypress Programmable System on Chip PSoC with 32 bit core ARM MCU.

SIMULATION OF THE REACTION OF DEUTERON FRAGMENTATION INTO CUMULATIVE AND DOUBLE CUMULATIVE PIONS

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We consider the fragmentation reaction of the incident deuterons with a few GeV energy into pions:

$$D + A_t = \pi(0^\circ) + X. \quad (1)$$

The paper presents results of simulations of the pion production cross section at zero angle as a function of the atomic mass of the target nucleus. Simulation was carried out for cumulative and double cumulative pions. For the reaction (1) a cumulative pion has momentum larger than maximal possible in the reaction [1-2]:

$$p + p = \pi(0^\circ) + X\ , \quad (2)$$

but less than the maximal momentum in the reaction:

$$D + p = \pi(0^\circ) + X. \quad (3)$$

It is assumed that the in the reactions (1) - (3) the energies per nucleon are identical. We define a double cumulative pion as a pion with momentum larger than the maximal possible momentum of the pion in the reaction (3) [3].

In the commonly accepted models cumulative particles are produced due to the high-momentum component of the fragmenting nucleus [4-5] (in the reaction (1) fragmenting nucleus is the deuteron). The source of this high-momentum component is a configuration wherein the distance between at least two nucleons is less than the average distance between nucleons in the nucleus [4-5]. According to [6], such configuration called a flucton. Within the framework of such models the double cumulative pions are produced due to configurations with fluctons in both colliding nuclei.

In this work we have shown that:

1. taking into account the re-scattering of hadrons, we can explain the observed in [7] the change in the cross section of deuteron fragmentation into pions from the atomic mass of the target nucleus in the transition from non-cumulative in the cumulative area.
2. in the double cumulative area the dependence on the atomic mass of the target nucleus is sensitive to the distribution of the fluctons in the target nucleus

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LOOP MIXING OF THE OPPOSITE PARITY FERMION FIELDS AND ITS MANIFESTATION IN πN SCATTERING

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We develop a variant of K-matrix, which includes the effect of opposite parity fermions (OPF) mixing, and apply it for description of πN partial waves S_{11} and P_{11}. OPF-mixing leads to appearance of negative energy poles in K-matrix and restoration of MacDowell symmetry, relating two partial waves. Joint analysis of PWA results for S_{11} and P_{11} confirms significance of this effect.
PACS: 13.75.Gx, 11.80.Et
Keywords: Fermion mixing; K-matrix approach

ANALYSIS OF INELASTIC PION-NUCLEUS SCATTERING WITHIN THE MICROSCOPIC OPTICAL POTENTIAL AND THE IN-MEDIUM EFFECT ON πN AMPLITUDE IN NUCLEI

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The microscopic model of optical potential (OP) [1] was adapted in [2, 3] for calculations of the pion-nucleus elastic and inelastic scattering cross sections. At present we apply this OP (its direct and transition parts) for further calculations of the $\pi^{\pm}$ + ^{28}Si, ^{58}Ni, ^{40}Ca, ^{208}Pb inelastic cross sections at energies 160, 180, 230, 290 MeV with excitations of the 2^+ and 3^- collective states of nuclei. In so doing we use the known nuclear density distributions and the parameters of the πN- scattering amplitudes obtained in [4] by fitting the calculated pion-nucleus elastic cross sections to the data. Thus for inelastic scattering, the only adjusted parameters were the quadrupole β_2 and octupole β_3 deformations inherent in transitions to the 2^+ and 3^- excited states of nuclei. The cross sections were obtained by solving the relativistic wave equation transformed to the nonrelativistic form when one obeys the high-energy condition $T \gg U_{opt}$. Then the equation was computed with a help of the DWUCK4 program [5], and thus the relativistic and distortion effects in initial and final channels of the process were accounted for automatically. The calculated cross sections were found to be in a fairly well agreement with the corresponding experimental data. One should underline an important role of the nuclear in-medium effect on the πN-scattering amplitude that reveals itself in the both elastic and inelastic scattering.

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PROTON STRUCTURE FROM HARD PP COLLISIONS AT LHC ENERGIES

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We present a review on the search for a signal of the possible Fock quark components in proton by the analysis of the hard pp collisions at the LHC energies. These so called intrinsic quark distributions have the x-dependence like the valence quark ones. Its probability to exist in proton is small, however it can be found analyzing the vector boson and photon production accompanied by the heavy flavour jets in pp collisions. To use the LHC potential, first of all, one should select the parton-level (sub)processes (and final-state signatures) that are the most sensitive to the intrinsic heavy quark contributions. To this end inclusive production of $c(b)$-jets accompanied by photons or vector bosons W, Z is considered. On the basis of performed theoretical study it is demonstrated that investigation of the intrinsic heavy quark contributions looks very promising at the LHC in processes like $pp \to \gamma + c(b) + X$, $pp \to W/Z + c(b) + X$.

FEMTOSCOPIC CORRELATIONS OF TWO IDENTICAL PARTICLES WITH NONZERO SPIN IN THE MODEL OF ONE-PARTICLE MULTIPOLE SOURCES

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The process of emission of two identical particles with nonzero spin S and different helicities is theoretically investigated within the model of one-particle multipole sources. Taking into account the unitarity of the finite rotation matrix and symmetry relations for d–functions, the general expression for probability of emission of two identical particles by two multipole sources with angular momentum J, averaged over the projections of angular momentum and over the space-time dimensions of the generation region, has been obtained. For the case of unpolarized particles, the additional averaging over helicities is performed and the formula for two-particle correlation function at sufficiently large 4-momentum difference q is derived . For particles with nonzero mass, this formula is simplified at the zero angle β between the particle momenta, and also at $J = S$.

The special cases of emission of two unpolarized photons by dipole and quadrupole sources, and emission of two "left" neutrinos ("right" antineutrinos) by sources with arbitrary J have been also considered, and the respective explicit expressions for the correlation function are obtained .

NUCLEON STRUCTURE IN LIGHT-FRONT QUARK MODEL CONSTRAINED BY ADS/QCD

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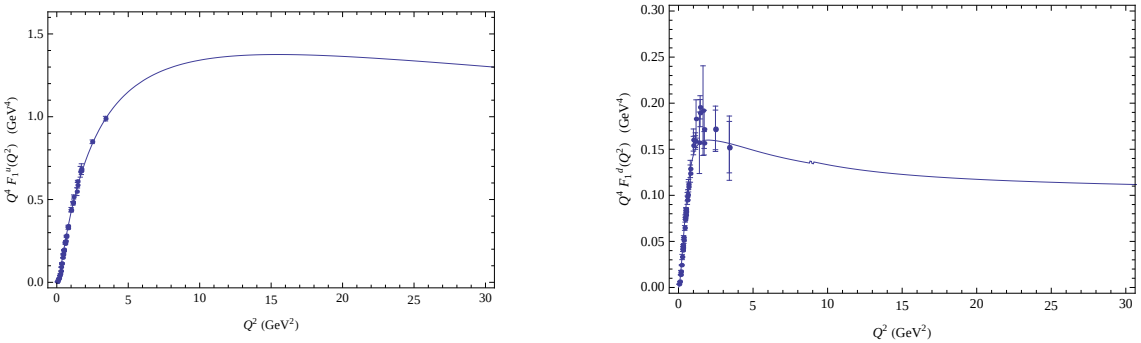
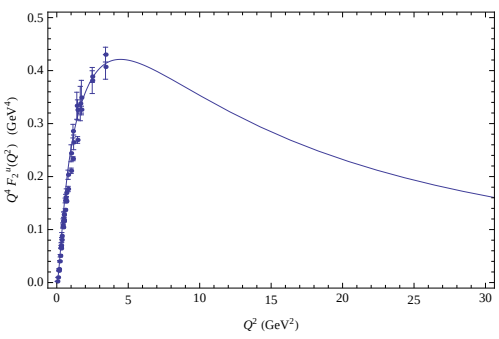
Using global fit of valence u and d quark parton distribution and data on quark and nucleon form factors we derive light-front quark model for the nucleon structure constrained by AdS/QCD [1] and consistent with quark counting rules. In particular, we propose the light-front wave function (LFWF) for nucleon as quark-scalar diquark bound state with a specific dependence on the transverse momentum $\mathbf{k}_\perp$ and the light-cone variable x. Selected results for electromagnetic form factors of nucleon including their u- and d-valence quark decomposition in comparison with data are shown in Table 1 and in Figs.1-4.

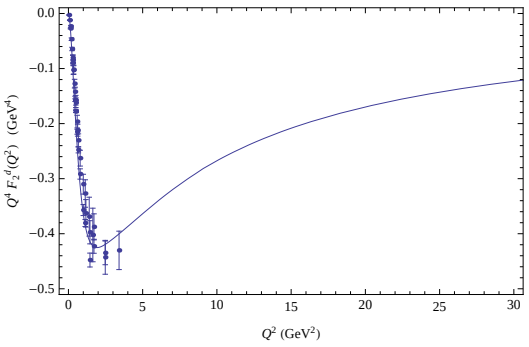
Table 1: Electromagnetic properties of nucleons

Quantity	Our results	Data
μ_p (in n.m.)	2.793	2.793
μ_n (in n.m.)	-1.913	-1.913
r_E^p (fm)	0.781	0.8768 ± 0.0069
$\langle r_E^2 \rangle^n$ (fm^2)	-0.113	-0.1161 ± 0.0022
r_M^p (fm)	0.717	$0.777 \pm 0.013 \pm 0.010$
r_M^n (fm)	0.694	$0.862^{+0.009}_{-0.008}$

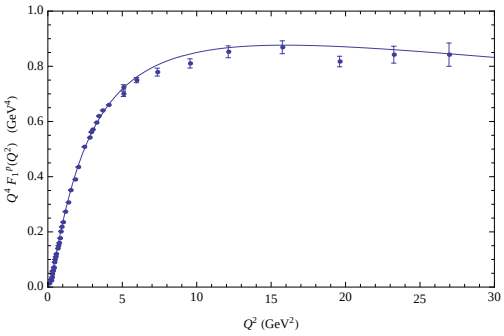


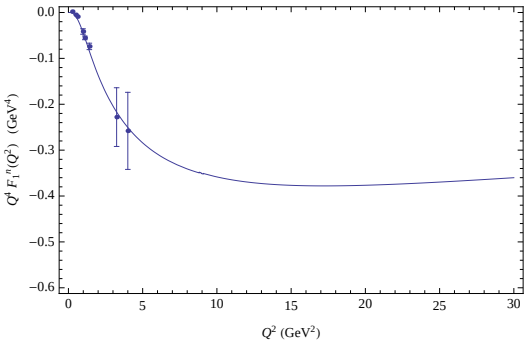
Dirac u and d quark form factor multiplied by Q^4



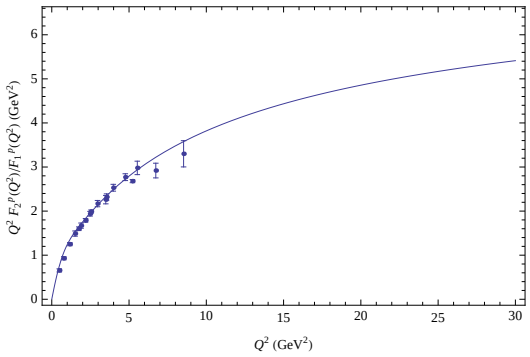


Pauli u and d quark form factor multiplied by Q^4





Dirac proton and neutron form factor multiplied by Q^4



Ratio $Q^2 F_2^p(Q^2)/F_1^p(Q^2)$

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HYPERFRAGMENTS FROM THE LIGHTEST P-SHELL HYPERNUCLEI. II. RECENT PROGRESS AND THE NEXT STEPS

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Background: The extension of the shell model for hypernuclei suggested by Gal *et al.* [1] is very successfully used in the interpretation the discrete part of spectrum of p-shell hypernuclei [2]. Recently in the experiment [3] the identification of ${}^{4}_{\Lambda}$H hyperfragment from the ^{9}Be target was confirmed.

Purpose: The advanced study of the strong decay of primary p-shell hypernucleus produced in reaction ${}^{A}Z(e,e'K+)^{A}_{\Lambda}(Z-1)$ [4] will determine the options of parsing still unexplored interval of this spectra.

Method: We extend Translation Invariant Shell Model [5] including the next excitation (N_{min}+2) and calculating 3-particle coefficients of parentage.

Result: We suggest the suitable targets and hyperfragments to be registered in the planned experiments [6, 7].

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HADRONIZATION MECHANISM AND SOLVABLE MODELS OF RENORMDINAMICS OF QCD

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Independently radiating valence quarks and corresponding negative binomial distribution presents phenomenologically preferable mechanism of hadronization in multiparticle production processes. Main properties of the renormdynamics, corresponding motion equations and their solutions are considered on the examples of QCD and other field theory models.

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SELF-SIMILARITY IN THE DESCRIPTION OF INCLUSIVE SPECTRA OF HADRONS PRODUCED IN *pp*- AND *AA*- COLLISIONS

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The use of the self-similarity allows us to describe rather well the ratio of the proton to anti-proton yields in *A-A* collisions as a function of the energy in a wide range from 10-20 GeV to a few TeV. Modification of our approach taking into account the energy dependence of inclusive spectra of hadrons allows us to describe the differential cross section as a function of m_T. We have got a satisfactory description of the slopes of the hadron spectra as functions of the energy in a wide range from AGS to LHC. Our approach describes rather well the mean transverse momentum squared of the K^- mesons produced in the central *A-A* collisions as a function of the energy.

FRAGMENTATION OF RELATIVISTIC ^{10}C RADIOACTIVE NUCLEI IN A TRACK NUCLEAR EMULSION

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The charge topology in the fragmentation of ^{10}C nuclei in a track nuclear emulsion at an energy of 1.2 GeV per nucleon is studied [1]. In the coherent dissociation of ^{10}C nuclei, about 82% of events are associated with the channel $^{10}\mathrm{C} \to 2\alpha + 2p$ [2]. The angular distributions and correlations of product fragments are presented for this channel. It is found that among $^{10}\mathrm{C} \to 2\alpha + 2p$ events, about 30% are associated with the process in which dissociation through the ground state of the unstable $^{9}\mathrm{B}_{g.s.}$ nucleus is followed by $^{8}\mathrm{Be}_{g.s.} + p$ decays.

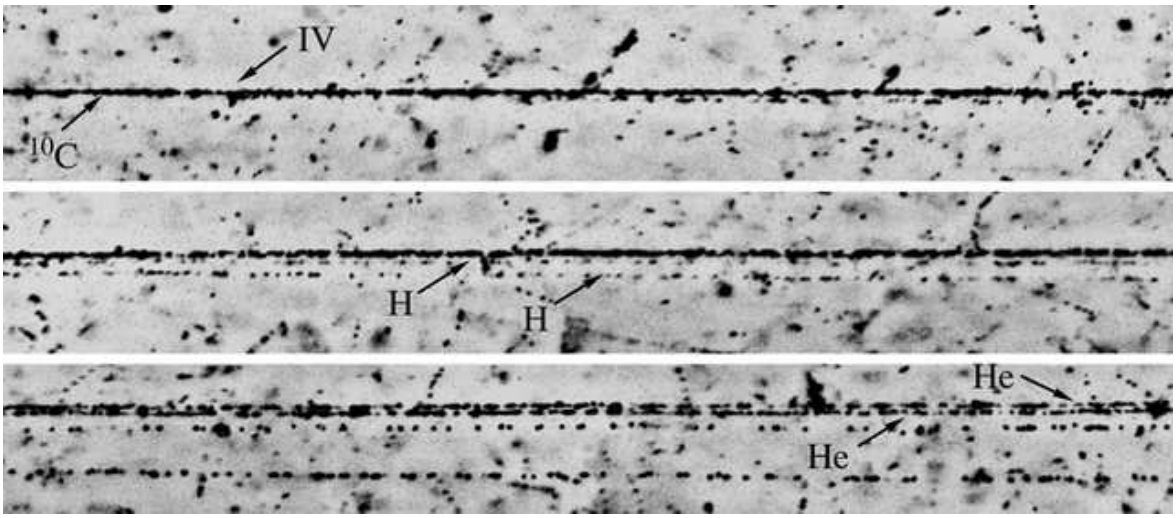

Figure 3: Successive macrophotographs of an event involving the dissociation of an ^{10}C nucleus at an energy of 1.2 GeV per nucleon. The arrows indicate the track of a beam ^{10}C nucleus, an interaction vertex (IV; at the top), and tracks of H and He fragments.

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HEAVY-LIGHT QUARKS INTERACTIONS IN QCD VACUUM

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Outline of the talk is:

- QCD vacuum, QCD instanton vacuum.
- Light quarks in the instanton background.
  - Light quark determinant.
  - Light quarks partition function.
- Heavy quarks in the instanton vacuum. Heavy quark propagator in the instanton vacuum with light quarks.
- Heavy-light quarks interactions.
  - Instantons generate nonlocal quark-quark interaction. Range of the nonlocality is about average instanton size $\rho \approx 0.3\, fm$.
  - It has a structure with 2 heavy quarks and $2N_f$ light quarks legs, whereN_f is a number of light quark flavors.
- As result, light quarks generate additional potential term in a heavy quark-antiquark system.
- Discussion.

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DOMAIN WALL NETWORK AS QCD VACUUM: CONFINEMENT, CHIRAL SYMMETRY, HADRONIZATION

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The ensemble of Euclidean gluon field configurations represented by the domain wall networks is considered. A single domain wall is given by the sine-Gordon kink for the angle between chromomagnetic and chromoelectric components of the gauge field. The domain wall separates the regions with Abelian self-dual and anti-self-dual fields. The network of the domain wall defects is introduced as a combination of multiplicative and additive superpositions of kinks. The character of the spectrum and eigenmodes of elementary color-charged fluctuations and colorless collective meson modes in the presence of the domain wall network is discussed. Conditions for the formation of a stable thick domain wall junction (the chromomagnetic trap) during heavy ion collisions are discussed, and the spectrum of color charged quasiparticles inside the trap is evaluated. An important observation is the existence of the critical size L_c of the trap stable against gluon tachyonic modes. The size L_c is related to the value of gluon condensate $\langle g^2 F^2 \rangle$. A short review of the quark confinement, chiral symmetry realization and hadronization formalism based on the ensemble of domain structured gluon fields is given. The concept of the confinement-deconfinement transition in terms of the ensemble of domain wall networks is outlined.

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MULTIFRAGMENTATION OF NUCLEI: NEW EXPERIMENTAL APPROACHES AND RESULTS

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A review of experimental data on multifragmentation of nuclei is given. New results obtained for the first time at the GRAAL facility with intermediate energy monochromatic photons using large aperture LAGRAN?E detector are presented. It is shown that electronic methods used at the GRAAL experiment allow obtaining new information about multifragmentation process in addition to the nuclear emulsion one. For example, cross sections, angular and energy distributions of products can be evaluated as function of multiplicity for separated meson photoproduction channels. New GRAAL data are compared with another results obtained with different projectiles. The principal interest of such comparison concerns the real and virtual photon interactions related to electromagnetic dissociation of relativistic nuclei in frame of the modern theoretical models.

BOSE-EINSTEIN EFFECTS IN MULTIPLICITY AND NET-CHARGE CORRELATIONS IN *pp* COLLISIONS USING PYTHIA8 SIMULATIONS

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Correlations between various observables, e.g. multiplicities of particles produced in *pp* collisions at the LHC energies within intervals separated in pseudorapidity and azimuth angle, could be a sensitive tool to analyze hadron collisions dynamics and test hadron production models.

In this report we present results of studies of multiplicity correlation coefficient topology for like- and unlike-sign pairs of charged particles using PYTHIA8 event generator [1]. Correlation coefficients were extracted using long-range forward-backward correlation method [2].

Peculiar behavior of correlation coefficient topology of net-charge is obtained in short-range region. Analysis shows that effects of Bose-Einstein statistics [3] have strong influence in this region of such correlations.

The results indicate the necessity of experimental studies of net-charge correlation topology that could bring new constraints to PYTHIA8 tunes.

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SPACE-TIME EXTENT OF PION SOURCE IN NUCLEAR-NUCLEAR COLLISIONS VERSUS INITIAL ENERGY

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The investigation of nuclear-nuclear collisions in wide energy domain with help of correlation femtoscopy seems important for better understanding both the equation of state (EOS) of strongly interacting matter and general dynamic features of soft processes. Energy dependence of femtoscopy characteristics of pion emission region at freeze-out will be discussed for collisions of various ions and for all experimentally available energies, in particular, comparison will be presented between RHIC and LHC results as well as for space-time extent of pion source in lower energy domain. For the first time the using of femtoscopy radii scaled on the averaged radius of colliding ions is suggested. This approach allows expand the set of interaction types, in particular, on collisions of non-symmetrical ion beams which can be studied in the framework of common treatment. Dependence of wide set of femtoscopy parameters on collision energy will be under consideration, in particular, scaled values for radii, for difference of squares of transverse radii with respect to the beam direction and for volume of source will be used for energy dependence. There is no sharp changing of femtoscopy parameter values, in particular, for ratio of out to side transverse radii with increasing of initial energy which was predicted by some phenomenological models as signature of first order phase transition in strongly interacting matter. Energy dependence of emission duration is almost flat for all energy range under study within large error bars.

PROTON FORM FACTORS IN SPACE-LIKE AND TIME-LIKE REGIONS

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Electromagnetic proton form factors are reviewed. All available data are presented and compared to theoretical models. Future perspectives at different facilities using elastic electron proton scattering in the space-like region and the annihilation reactions in the time-like region are summarized. Possible physical interpretations of form factors are attempted on the basis of the need for a global description in the full kinematical region.

COMPARISON BETWEEN DEUTERON AND CARBON BEAMS AT "QUINTA" SET-UP

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The distributions of fission and capture reactions for deuteron and carbon beams with energies 2 AGeV and 4AGeV in the extended uranium target "Quinta" are analyzed in the present work. The experimental results are compared with the simulation realized in Geant4. Two models for the hadron inelastic interaction were used in the simulation: binary cascade (BC) and Liege cascade (INCL). At radius 0 cm the simulations realized realize values for fission 2 -3 times higher than the experimental distributions. At radiuses between 4 and 12 cm the agreement between experimental data and simulation is good (in the limits of 30 %), except the data for carbon beam 4 AGeV. In this case the experimental values for both fission and capture are higher than the simulated ones. The discrepancies between experimental data and simulation are analyzed. In spite of these differences both experimental and simulated data show the advantage of using carbon beams in comparison with deuteron for ADS. For the same energy spent to accelerate the projectile the ratio between the total number of fission generated in the target for carbon and deuteron with the energy 2 AGeV is 6.72 (experiment), 4.55 (BC) and 4.37 (INCL). For projectile energy 4 AGeV the corresponding ratios are 6.29 (experiment), 5.48 (BC), and 5.16 (INCL).

NON-EXTENSIVE STATISTICS EFFECTS IN TRANSVERSE MOMENTUM SPECTRA OF CHARGED PARTICLES IN HIGH-ENERGY COLLISIONS

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The transverse momentum distributions measured by the ALICE, ATLAS and CMS Collaborations at the LHC and by the STAR and PHENIX Collaborations at the RHIC are analyzed in the framework of the relativistic non-extensive Tsallis statistics. The thermodynamic consistency of the Tsallis statistics in the particular case of the non-relativistic ideal gas in the microcanonical and canonical ensembles is proved. The estimates of the Tsallis parameters q, T and the volume for the transverse momentum spectra are presented.

THE FORM FACTORS OF THE NUCLEONS

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The introduction of the double polarization experimental technique for the measurement of the four elastic form factors of the nucleons, G_{Ep}, G_{Mp} and G_{En}, G_{Mn}, has resulted in much theoretical activity. The new results for the proton in particular, are strongly at variance with the cross section data base; they are also of greater accuracy.

Here we will review the experimental data base in view of the new results for the proton and the neutron, obtained at MIT-Bates, MAMI and JLab. The rapid evolution of phenomenological models triggered by these high-precision experiments will be discussed. In particular, the possibility that the proton is non-spherical in its ground state, that radial densities for the electric and magnetic charge and currents are well defined in the infinite momentum frame, and different from the ones obtained by Fourier trasnform from the Breit frame, that flavor decomposition into the dressed u and d quark form factors may give information about the quark-diquark structure of the nucleon.

THE DIRAC THEORY AND CONFINEMENT

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Space-time is a mathematical space whose points must be specified by both space and time coordinates. A comparison of the Dirac theory of the electron with spin in a mathematical space with the original Dirac theory in the Minkowski space-time is produced. New representations about nature of space, time, rotation, quark-lepton symmtry and confinement are derived from this consideration.

W PAIR PRODUCTION IN $\bar{p}p$ COLLISIONS AT 1.96 TeV

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For the CDF Collaboration

The University of Wisconsin, Madison

Pairs of W bosons can be produced by *s* channel triple gauge boson coupling, or by *t* channel quark radiation. This *WW* cross section measurement used selection techniques similar to the Tevatron $H \rightarrow WW$ search. A neural net was trained to distinguish *W W* signal from background. The *WW* cross section was then extracted by a maximum likelihood method fit to the *WW* and background neural net shapes. The *WW* cross section is presented both inclusively and differentially in jet multiplicity. The analysis uses the full 9.7fb^{-1} CDF dataset. The measured inclusive cross section is $\sigma(\bar{p}p \rightarrow W^+W^- + X) = 14.0 \pm 0.6(\text{stat})^{+1.6}_{-1.3}$ (syst) ± 0.84(lumi) pb.

THE 2 REGGEONS TO 2 REGGEONS + PARTICLE EFFECTIVE VERTEX ($A_+A_+A_-A_-V_\nu$) IN THE LIPATOV EFFECTIVE ACTION FORMALISM

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We study the processes of nucleus-nucleus interaction. The bulk of the amplitude can be represented in terms of pomerons propagating from the multi-nucleon projectile to the multi-nucleon target. The pomeron couples to the separate valence quarks in a hadron, rather than to the hadron as a whole. This particular assumption forms the basis of an internally consistent and extremely successful model. It is consistent with experiment. Phenomenological properties of the pomeron are derived from high energy qq and $\bar{q}q$ total and differential cross-section data. Each pomeron can also split into two ones through a certain known triple pomeron vertex (pomeron fan diagrams) or interacts by means of less known multipomeron effective vertices. Our aim is to analyse, if apart from the triple-pomeron coupling one has to account couplings of a larger number of pomerons in nucleus-nucleus interactions.

Our immediate problem is to take into account the four-pomeron interaction, which appears when two nucleons from the projectile nucleus interact with two nucleons from the target nucleus in a non-trivial way, that is, with a connected diagram. In the lowest order each nucleon can be imitated by a quark-antiquark loop with at least two gluons attached to it. Still more simplifying, we can substitute the loop by a single quark, provided we assume that it interacts with a double gluon exchange in the colourless state.

This is the problem to be solved by calculating effective vertex $A_+^{B_1}A_+^{B_1}A_-^{b_1}A_-^{b_2}V_\nu^d$

To study this process we use the Lipatov effective action, which provides a powerful and constructive technique for the calculation of all Feynman diagrams in the Regge kinematics.

In my report I would like to talk about the problem arising in $3 \to 3$ reggeons transition, which includes the effective vertex.

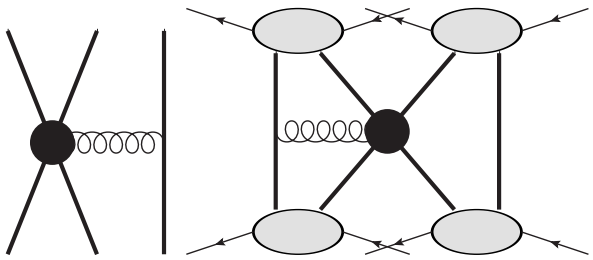

Figure 4: $A_+A_+A_-A_-V_\nu$ effective vertex (left); process of interaction of two quark pairs (right).

The authors (S.P. and M.B.) acknowledge Saint-Petersburg State University for a research grant 11.38.197.2014

NUCLEON FORM FACTOR MEASUREMENTS WITH 12 GeV CEBAF AT JEFFERSON LAB

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Jefferson Lab's upgrade will double the electron beam energy to 12 GeV. The doubling of the energy will allow the extension of recent programs to fully characterize the electric form factors of the proton and neutron to significantly higher Q^2. In this presentation, I will describe the upgrade of the accelerator and the new planned experiments to measure the nucleon form factors. I will also quickly review the present status of the nucleon form factors and discuss a number of recent theoretical approaches.

RECENT RESULTS FROM PHENIX ON JET SUPPRESSION AND DIRECT PHOTON PRODUCTION

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It has been established that a new state of matter called strongly interacting quark-gluon plasma (sQGP) is created in heavy ion collisions at RHIC energies. Detailed study of the properties of this hot and dense matter has been a primary purpose of research at RHIC over the last years. Hard scattered partons loose significant part of their energy traversing the medium produced in heavy ion collisions resulting in suppressed production of high p_T hadrons or jet quenching. As a result high p_T hadrons and jets are a sensitive probe of opacity of the produced medium. At intermediate p_T hadron production is driven by competing particle production mechanisms which are sensitive as to high-p_T phenomena as to collective effects in the produced medium which are a subject of special interest. The electromagnetic probes such as direct photons are not affected by strong nuclear forces. They are extremely valuable in study of the jet quenching phenomena. In addition measurement of direct photon produced at all stages of the interaction allows to constrain the time evolution of the medium. In this talk we present recent PHENIX results for system size and energy dependence of high p_T hadron suppression in heavy ion collisions. Dependence of intermediate p_T hadron production on particle mass and quark content is discussed. We also report latest results for direct photon production along with centrality dependence of soft direct photon yields, second and third order azimuthal anisotropy v_2 and v_3 at low momentum in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

EXPERIMENTAL SET-UP MARUSYA-FLINT FOR THE STUDY OF CORRELATIONS IN CUMULATIVE PROCESS AT NUCLOTRON-M BEAMS. CURRENT STATUS

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The experimental program for the study of properties of cold superdense matter is proposed for NUCLOTRON accelerator at the Joint Institute for Nuclear Research in Dubna. The region of phase diagram of nuclear matter with temperature and baryon density typical for neutron stars will be studied at the laboratory. Experimental setup for this program is created on the basis of synthesis experiments MARUSYA (JINR) and Flint (ITEP).

The high transverse momentum particles in the central rapidity region will be used as a trigger to select events with cold superdense matter droplet production in relativistic nuclear collision.

Setup MARUSYA-FLINT includes the target station, system for beam monitoring, multiplicity detector and two arms for registration of secondary particles. The trigger arm is built on the electromagnetic calorimeter. Baryon arm (in the opposite of the azimuthally direction) includes magnetic lenses and bending magnets, scintillation hodoscopes, proportional chambers, Cherenkov counter and the neutron detector. Polar angle for this arm can be change from 23 to 90 degrees.

Present status of experimental setup and beam test results are discussed in the report.

IDENTIFYING LARGE EXTRA DIMENSIONS IN LEPTON PAIR PRODUCTION AT THE LARGE HADRON COLLIDER

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Arkani-Hamed, Dimopoulous, and Dvali have proposed a model (ADD) of low-scale quantum gravity featuring large extra dimensions [1]. In this model, the exchange of Kaluza-Klein towers of gravitons can enhance the production rate of lepton pairs at high invariant mass in proton-proton collisions at the LHC. By considering the present and future LHC energy regimes, we reanalyse the potential of the LHC to discover the effects of large extra dimensions and to discriminate between various theoretical models. Specifically, in latter case we explore the capability of the LHC to distinguish spin-2 Kaluza-Klein towers of gravitons exchange from other new physics effects which might be conveniently parametrized by the four-fermion contact interactions [2, 3]. We find that the LHC with planned energy 14 TeV and luminosity 100 fb^{-1} will be capable of discovering (and identifying) graviton exchange effects in the large extra dimensions with the cutoff parameter of order $M_S = 6.2$ TeV (4.8 TeV) for d = 6 and $M_S = 8.8$ TeV (6.8 TeV) for d = 3.

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MEASUREMENT OF THE SPIN-DEPENDENT OBSERVABLES IN ELASTIC NN COLLISIONS AT NICA

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The possibilities for investigation of the elastic NN scattering observables at NICA collider are shown. The unpolarized differential NN cross section I_{oooo}, analyzing powers for primary reactions with polarized beam A_{oono} or target A_{ooon}, and spin correlation parameters A_{oonn} and A_{ookk} in primary reactions with the beam and target both polarized can be measured.

The planned luminosity of the polarized nucleon colliding beams allows to obtain event rate high enough for such measurements. Usage of colliding polarized nucleon beams for these observables measurement has a number of significant preferences with comparison to the "fixed" target experiments (detectors angular acceptance over full solid angle, wide energy range, "target" without background impurities).

CLOTHED PARTICLES IN MESODYNAMICS, ELECTRODYNAMICS AND OTHER QUANTUM FIELD MODELS

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First, we will show how the notion of clothing in quantum field theory, put forward by Greenberg and Schweber [1], can be used not only in the theory of interacting meson and nucleon fields (see, e.g., our previous works [2]–[6]), but in the quantum electrodynamics (QED) (cf. an akin approach developed in ref. [7]). As before, handling the instant form of relativistic dynamics and applying the method of unitary clothing transformations (shortly, the UCT method) we have derived a novel analytic expression for the QED Hamiltonian in the clothed particle representation (CPR) in which the so-called bad terms are simultaneously removed from the Hamiltonian and boosts via one and the same UCT. In spite of the primary electromagnetic(EM)interaction has been chosen in the Coulomb gauge (CG) with an apparent violation of the Lorentz invariance the property is restored owing to the cancelation of the noncovariant Coulomb interaction contribution already with the first clothing transformation. A similar cancelation has been found [5] in case of the vector mesons (spin 1 bosons) interacting via the Yukawa-type couplings with the nucleons (spin $\frac{1}{2}$ fermions). Second, we are trying to realize this notion in the quantum chromodynamics (QCD) (to be definite for the gauge group $SU(3)$) when drawing parallels between QCD and QED. It is convenient to do it along the guideline: the well-known QCD Lagrangian density with the hermitian and traceless vector potentials, the mass and covariant derivative matrices in color space, the color-Maxwell equations and the color gauge-invariant energy-momentum stress tensor versus their colorless counterparts in QED (cf. survey [8]).

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QCD INSPIRED MESON MODEL AND SWINGER-DYSON EQUATION FOR MASSLESS QUARK

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We present ideas that are usually not taken into account in QCD studies: importance of formulation in Minkowski-spacetime and effect of an operator product expansion by means of normal ordering of fields in lagrangian. The formulation of QCD in Minkowski-spacetime allows us to solve an constraint equation. This follows to decompose an gauge field propagator in sum of instantaneous part (which forms a bound state) and retarded part (relativistic corrections). Usually in Quantum Field Theory a Lagrangian is considered as normal ordering function of all operator fields. We show that if it is not so, a gluon condensate is appear, which naturally leads to a low energy effective gluon mass. Then we derive a Schwinger–Dyson equation for quark, nontrivial solution of this equation leads to spontaneous breaking of chiral symmetry. The resulting Swinger-Dyson equation was studied both analytically and numerically. In this article we was considered as simple model as possible, with one flavor massless quark, but our methods can be used in more general case.

PROCESSES WITH HIGH p_T BEYOND THE STANDARD PARTON MODEL

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At the present time, the study of processes with high p_T found a number of effects that are not find explanations in the framework of the standard parton model. They are "$p_T \sim$ 2 GeV/c anomaly", data of cumulative particle production in the high p_T region, particle production with high p_T in pA - collisions and other. Will be discussed experiments that might shed light on the possibility to presence of multi-quark configurations in baryons and nuclear matter.

PHENOMENOLOGICAL DESCRIPTION OF ELECTROMAGNETIC AND STRONG INTERACTIONS IN ROTATING FRAMES AT COLLISIONS OF HIGH ENERGY NUCLEI

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Peripheral collisions of high energy nuclei can be characterized by large angular momenta. Such collisions are planned to be studied at the NICA accelerator complex at JINR. When nuclei rotate with a very large angular velocity [1, 2], a description of physical phenomena in a rotating frame is rather helpful. For such a description, we use the initial covariant Dirac equation defining electromagnetic and gravitational (or inertial) interactions of a spin-1/2 fermion. To provide a phenomenological description for strong interactions, we add conventional vector and scalar confining potentials (Coulomb plus linear ones) to this equation. We perform the Foldy-Wouthuysen (FW) transformation by the method [3] applicable for a relativistic particle in strong external fields. The derivation of the relativistic FW Hamiltonian makes it possible to give a detailed quantum-mechanical analysis of the problem and to obtain a unambiguous classical limit of the initial equation. The obtained results show a strong influence of the rotation on the motion of quarks and the dynamics of their spins.

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HIGH PRECISION MEASUREMENTS OF CROSS-SECTIONS IN $A(d,p)X$ REACTIONS AT SMALL INTERNAL PROTON MOMENTA

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The measurements were performed on the the nuclotron extracted deuteron beam of 3.5 GeV/c using STRELA spectrometer. The carbon and CH_2 target were used. The spectra were obtained in 0-0.3 GeV/c proton momenta in the deuteron rest frame. The wide momentum acceptance of the setup allowed to avoid acceptance corrections. The direct measurement of the input particle tracks allowed to evaluate reliably absolute values of cross-sections. The data are compared with previously obtained data [1].

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SPACE-DYNAMIC CORRELATIONS IN QUASI-TWO-PARTICLES π+Xe → π+N INTERACTIONS AT GeV ENERGY REGION

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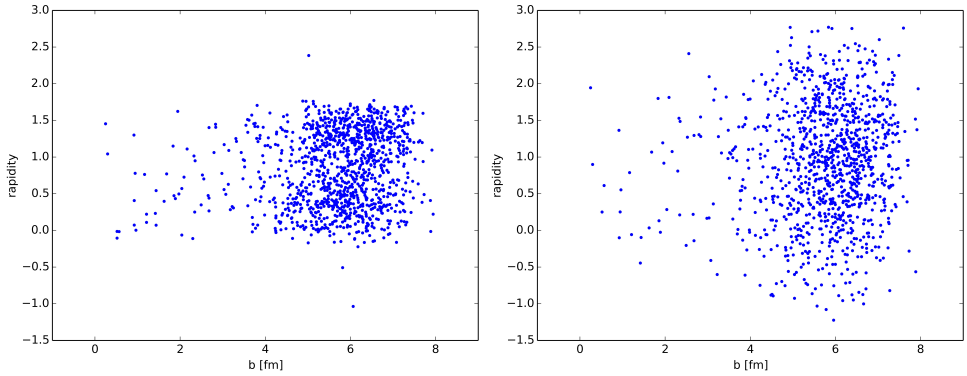
It is commonly known that the impact parameter (IP) is a very important quality determining the initial interaction geometry of hadron-nucleus interactions. But directly measured are momenta and energies of identified secondary particles only. So, the question arises whether and to what extend one can estimate the range of IPs at which a specific channel of the reaction occurred. To clear up this problem it is appropriate to analyze the correlation between some constructions of the measured features and IP using reliably established modeling codes.

Earlier [1] we investigated the correlation between multiplicity, rapidity and IP (b) of charged pions, protons and neutrons produced in π+Xe interactions at intermediate energies by means of a JAM modeling code and found that there exists some meaningful correlation between IP and both the average multiplicity and average rapidity of produced particles and it is possible in principle to infer more than simply qualitatively about the initial interaction geometry on the basis of available observables.

Among the multiplicity of channels of nuclear reactions the quasi-two-body ones play particular role, in particular, as a probe for investigation of nontrivial components of nuclear structures (for example, [2,3]). Therefore, in our work we study the correlation between the rapidity, transverse momentum and b in quasi-two-particles π+Xe interactions at GeV energy region in order to clarify the possibility of plausible estimation of IP interval where these reactions occur. The work has been performed using the JAM simulation code.



An example of our results: Scatter plot of rapidity vs impact parameter for $\pi^+ + Xe \rightarrow \pi^0 + p + (p/n/\pi^{\pm}) + A$ at 2.34 GeV/c (left - for protons, right - for π^0). Modelled by using JAM code.

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NEUTRONS PRODUCTION IN HEAVY SPALLATION TARGETS BY ELECTRONS BEAMS

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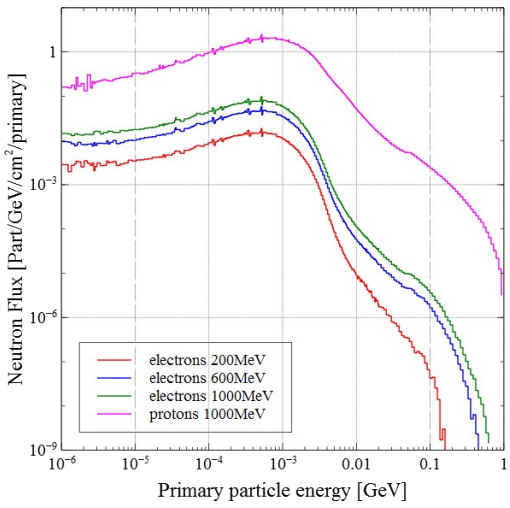
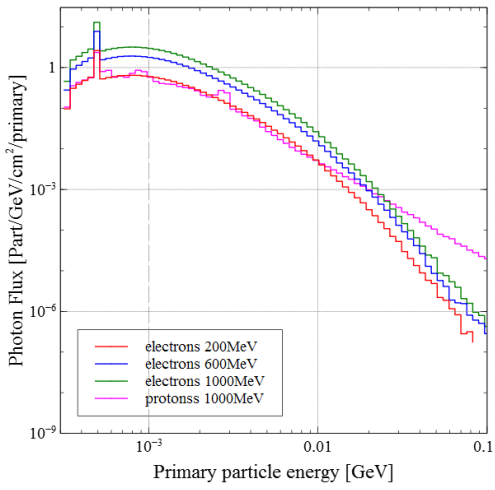
One of the main problems of present and future nuclear power is safe and rational management of radioactive wastes from nuclear plants, in particular, by means of transmutation and incineration in appropriate neutrons fields. Although it is commonly accepted that for this purpose optimal are ~1 GeV protons producing neutrons in heavy spallation targets like Pb, W and U, but accelerators of such beams are expensive and not available in many laboratories. Therefore, the keen interest for neutrons generation has also displayed in electronuclear reactions initiating by electrons because the relevant accelerators are much cheaper and sufficiently popular.

In the work we compare the results of our calculation of energy spectra of the neutrons produced in heavy spallation targets performed as Pb and W rods by electrons from 200 MeV to 1 GeV with similar distributions of neutrons generated by 1 GeV protons in the same targets. As the conclusion it is stated that the shape of neutrons energy spectra created by both 1GeV protons and electrons are acceptably comparable below ~1 MeV whilst above this value electronuclear neutrons are numerous enough to be used as a spallation neutron source for several aims like transmutation and incineration at least at the experimental level. Additionally, the heat release and remnant radioactivity of the investigated targets have also been estimated. All calculations are performed by using MCNPX and FLUKA codes. As an illustration, the figures demonstrated a comparison of energy spectra of neutrons and photons produced in a lead target by electrons and protons at different energies [1].





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THOROUGH INVESTIGATION OF ELECTROMAGNETIC CASCADES PRODUCED BY GAMMA QUANTA UP TO 100 GEV IN HEAVY AMORPHOUS MEDIA

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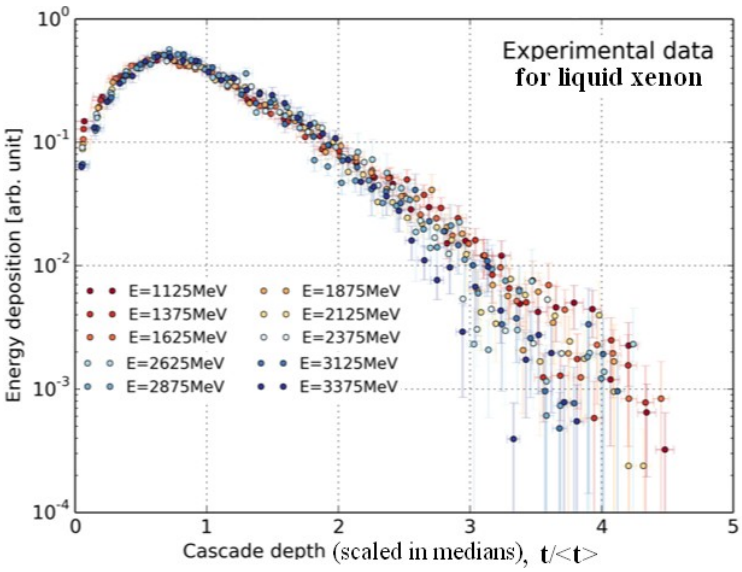
It is well known that the process of electromagnetic cascade (EC) created by high enough energy gamma quanta (GQ) or electrons (≳100 MeV) and developing in dense amorphous materials (DAMs) is a succession and superposition of mainly four elementary electromagnetic phenomena: pair production, gamma radiation (bremsstrahlung), ionization and multiple Coulomb scattering. The knowledge of this process is necessary, in particular, for detectors and shielding construction, energy reconstruction of primary GQ and electrons, estimation and prognosis of radiation degradation of materials etc. Presently in use is practically the simplest and rough description of basic features of ECs induced in dense and heavy materials by high energy GQ: longitudinal profiles (LPs) and several integral formulas describing the average longitudinal energy deposition (profiles) of ECs (for example, [1,2]). Nevertheless, such a qualitative model is not too adequate, especially at large depths t and at the very beginning of the cascade [2].

In the work we study the average longitudinal profiles of ECs created in eight most popular dense amorphous media: liquid xenon, PWO, $CdWO_4$, GaAs, NaI, Pb, lead glass and BGO by gamma quanta of energy E_γ = 100MeV÷100GeV at two different cut-off energies E_{co} of electrons and positrons (later on: electrons): 1.2 and 3.0 MeV taking account the effect of back-scattering at the very beginning and energetic inhomogeneity of electrons at the end area of cascades. Moreover, to compress such a copious experimental information about EC it is quite reasonable to find some scaling description of LPs making them at least energy independent and we found that the average cascade depth $<t>$ is quite good candidate. In addition, this parameter reveals a simple dependence of E_γ: $<t> \sim \ln E_\gamma$.



The work has been performed using GEANT4 modeling codes [3] and experimental data from Xe bubble chamber of ITEF (Moscow) [2]. For every set of parameters: E_γ, E_{co} and material we modeled 20000 events (histories). The objective of this investigation is to obtain simple formulas describing average profiles of ECs, as well as fluctuations and correlations suitable for practical applications.

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WKB - TYPE APPROXIMATIONS IN THE THEORY OF VACUUM PARTICLE CREATION IN STRONG FIELDS

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The effect of vacuum particle creation in constant fields was predicted just as a tunneling mechanism [1]. It created the illusion that the WKB approach for relativistic fields is correct also in the case of fastly varying external fields. This religious belief generated series of works devoted to estimations of the efficiency of vacuum electron-positron pairs (EPP) creation with spatially homogeneous models of the periodically time-dependent electric field.

In the present work we use the possibility to compare these results with the numerical calculations based on a kinetic equation that is a strong consequence of the basic equations of motion of QED [2]. This approach was used widely for investigation of EPP creation in strong laser fields in the case of linearly polarized electric fields [3]. This comparison showed that the WKB type approximation is valid only in the range of the validity of the tunneling mechanism that corresponds to the small adiabaticity parameter $\gamma = E_c\omega/E_0 m \ll 1$, where E_c is the Schwinger critical field strength and E_0, ω are amplitude and frequency of the laser field, resp. Increasing γ and entering the multiphoton region is accompanied by a catastrophic breakdown of the qualitative argument in the tunnel domain. This conclusion is in accordance with the work [4] showing that the non-stationary tunneling problem meets with difficulties manifesting themselves by an irregular dependence of the results on the energy.

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POLARIZED NONSINGLET Δq_3 AND NONSINGLET FRAGMENTATION FUNCTION $D_{u_v}^{\pi^+}$ IN THE ANALYTIC APPROACH TO QCD

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The results of QCD analysis of a set of deep inelastic scattering 'fake' data on the $\Delta q_3(x,Q^2)$ and the $D_{u_v}^{\pi^+}(z,Q^2)$ based on the APT approach [1] are presented. The 'fake' data were constructed based on the parametrization of polarized PDF [2] and nonsinglet combination of the pion fragmentation functions [3].

In the leading order the nonsinglet moments evolve as

$$\mathcal{M}^{\rm APT}(N,Q^2)=\frac{\mathcal{A}_\nu(Q^2)}{\mathcal{A}_\nu(Q_0^2)}\,\mathcal{M}^{\rm APT}(N,Q_0^2)\,,\quad \nu(N)=\gamma_{NS}^{(0),N}/2\beta_0,\ N=2,\ 3,\dots\,, \qquad (1)$$

where the analytic function $\mathcal{A}_\nu$ is derived from the spectral representation and corresponds to the discontinuity of the ν-th power of the PT running coupling. One loop result can be presented in the form: $\mathcal{A}_\nu^{LO}(Q^2,\Lambda^2)=\left[a_{\rm PT}^{LO}\left(\frac{Q^2}{\Lambda^2}\right)\right]^\nu-{\rm Li}_{1-\nu}\left(\frac{\Lambda^2}{Q^2}\right)/\Gamma(\nu)$ [4]. The analysis shows that the analytic approach provides reasonable results in the QCD analysis. We confirm an inequality $\Lambda_{\rm APT}>\Lambda_{\rm PT}$ obtained in our previous analysis of the xF_3 structure function data [5].

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LORENTZ BOOSTS IN INTERACTING SYSTEMS

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In quantum systems, interaction is normally modeled by adding a potential energy operator to the generator of time translations – the Hamiltonian. It is less known that in order to maintain the Poincaré invariance, a special interaction operator must be also added to the generator of Lorentz boosts. In this talk we will discuss possible observable consequences of such "boost interactions".

While interaction in the Hamiltonian reveals itself by a non-trivial time evolution of the system, boost interactions should lead to non-standard transformations of observables to the moving inertial reference frame. The famous theorem [1] states that a multi-particle system, whose trajectories transform by usual Lorentz formulas, ought to be non-interacting. We will illustrate this theorem by three examples of fully relativistic models having non-conventional behaviors under boosts.

The first example is an one-dimensional classical two-particle system [2]. Numerical simulations of trajectories were performed in two reference frames in relative motion. These results confirmed the statement of the Currie-Jordan-Sudarshan theorem: simple Lorentz transformation formulas are not applicable to the trajectories of interacting particles.

The second example is an oscillating $\mu-\tau$ neutrino pair in an one-dimensional Hamiltonian model [3]. Analytical solutions were obtained. In addition to usual flavor oscillations there were also velocity oscillations of the two neutrino species. During brief time intervals the velocities exceeded the speed of light.

In the third example, we consider the decay law of an unstable particle observed from a fast-moving inertial frame [4, 5]. Numerical simulations showed that the usual Einstein's time dilation formula was not accurate in this case. Small corrections to this formula were calculated and analyzed.

Remarkably, in all the above examples we employed truly relativistic Hamiltonian models, but found deviations from usual special-relativistic predictions. Unfortunately, in realistic physical systems these deviations are too small to be observed experimentally.

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IMPLEMENTATION OF A CELLULAR AUTOMATON METHOD FOR TRACK RECONSTRUCTION IN THE INNER TRACKING SYSTEM OF MPD

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A track reconstruction method based on a cellular automaton concept has been developed and implemented for the inner tracking system (ITS) of the MPD experiment at NICA. The reconstruction algorithm will be briefly described and some obtained results presented.

STUDIES OF RELATIVISTIC DEUTERON REACTION CROSS-SECTIONS ON COPPER BY ACTIVATION METHOD

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The international collaboration Energy and Transmutation of Radioactive Waste (E&T RAW) in the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, performed intensive studies of simple accelerator-driven system (ADS) set-ups irradiated by proton and deuteron beams in the past years. Suitable activation detectors serve as one of possible tools for monitoring of proton and deuteron beams and for neutron field measurements in ADS studies as well.

The cross-sections of relativistic deuteron reactions on natural copper were studied in detail by means of activation method. The copper foils were irradiated during experiments with the Quinta and Gamma model targets in the VBLHE JINR. The deuteron beams with energies ranging from 1 GeV up to 8 GeV were produced by JINR Nuclotron accelerator. Residual nuclides were measured by the gamma spectrometry. Lack of such experimental cross-section values prevents the common use of copper foils from deuteron beam integral monitoring. The Nuclear Physics Institute (NPI) group commonly uses activation detectors not only for beam monitoring but also for determination of neutron field spatial distribution and proper beam integral determination preferably from multiple reactions is important for our measurements. The copper monitors will help us to improve the beam integral determination during our future ADS studies.

We use in the first place aluminium foils and ^{24}Na production reaction for beam monitoring. Large distance from the irradiated set-up is necessary in this case due to production of ^{24}Na also by neutrons. On the other hand, the determination of the deuteron production of radionuclides on copper monitor is not influenced by MeV neutron reactions and such monitor can be placed near the set-up. Thus, an improvement of our knowledge of excitation functions of various radionuclides production on copper by relativistic deuterons is necessary. These are mostly unknown unlike the proton cross-sections in the examined energy range. Therefore, we measured cumulative cross-sections of different radionuclides production by deuterons on copper. Cross-sections of more than 30 isotopes were determined using gamma spectrometry. The obtained data will enable to use copper beam monitors during ADS experiments with deuterons in the years to come. The second main goal of these studies is to provide a database for evaluation of models used for prediction of the production of different radionuclides by relativistic deuterons in various fields of application.

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THE EFFECT OF PROCESSES $\pi\pi \to \pi\pi, K\overline{K}, \eta\eta$ IN DECAYS OF THE ψ- and Υ-MESON FAMILIES

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The effect of isoscalar S-wave processes $\pi\pi \to \pi\pi, K\overline{K}, \eta\eta$ is considered in the analysis of data (from the Argus, Crystal Ball, CLEO, CUSB, DM2, Mark II, Mark III, and BES II Collaborations) on decays of the charmonium – $J/\psi \to \phi(\pi\pi, K\overline{K})$ and $\psi(2S) \to J/\psi(\pi\pi)$ – and of the Υ-meson family – $\Upsilon(2S) \to \Upsilon(1S)\pi\pi$, $\Upsilon(3S) \to \Upsilon(1S)\pi\pi$ and $\Upsilon(3S) \to \Upsilon(2S)\pi\pi$. The analysis, which is aimed at studying the scalar mesons, is performed jointly considering the multi-channel pion-pion scattering, which is described in our model-independent approach based on analyticity and unitarity and using an uniformizing variable method, and the decays under reasonable assumptions. Results of the analysis confirm all our earlier conclusions on the scalar mesons. It is also shown that in the final states of the ψ and Υ-meson family decays (except for the $\pi\pi$ scattering) the contribution of the coupled processes, e.g., $K\overline{K} \to \pi\pi$, is important even if these processes are energetically forbidden. This is in accordance with our previous conclusions on the wide resonances. E.g., a new and natural mechanism of destructive interference in the decay $\Upsilon(3S) \to \Upsilon(1S)\pi\pi$ is indicated on the basis of that consideration, which provides a characteristic two-humped shape of the di-pion mass spectrum.

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LEAD SHIELDING IMPACT ON FAST NEUTRON SPECTRUM (>10MeV) IN QUINTA URANIUM TARGET

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The QUINTA uranium target is a deeply subcritical active core consisting of 512 kg of natural uranium rods arranged hexagonally. The target is irradiated by a pulsed beam of relativistic ions using the JINR NUCLOTRON accelerator. In the paper the lead shielding impact on fast neutron spectrum in the QUINTA uranium target is studied. The fast neutron energy spectra inside the volume of the QUINTA uranium target using threshold reaction in natural yttrium (^{89}Y) were measured for the same deuteron energy of 4 GeV when the uranium target of the assembly was enfolded with the lead shielding and without the shielding. The (n,xn) reaction rates of yttrium samples located inside the assembly were determined through gamma spectrometry. The measurement show that the neutron flux density increases in whole volume of the QUINTA assembly due to the lead shielding. The lead shielding influence on the neutron spectra is more pronounced in the volume located closer to the shielding.

SPIN OBSERVABLES OF PD-SCATTERING AND TEST OF T-INVARIANCE

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Time-reversal invariance will be tested in proton-deuteron scattering in an internal target transmission experiment at COSY [1]. The integrated cross section $A_{y,xz}$ will be measured for transverse polarized proton beam (P_y) and tensor polarized deuterium target (P_{xz}). This observable provides a real null test of time invariance violating but P-parity conserving forces which do not arise in the standard model as a fundamental interaction, and this signal is not affected by the final state interaction. To take under control background conditions of this experiment and estimate its accuracy one has to know magnitudes of several T-even, P-even spin-observables in pd scattering at energy of the planned experiment 100-200 MeV. In the present work the differential spin observables of the elastic pd scattering and total pd cross sections for polarized proton and deuteron are calculated within the Glauber theory. We use the formalism of [2] and develop it for inclusion of T-odd pN-scattering amplitudes. Furthermore, we properly modify the formalism of [2] to make a comparison with existing experimental data. The results of our calculations for unpolarized differential cross section, vector A_y and tensor A_{ij} analyzing powers and spin correlation parameters C_{ij}, $C_{ij,k}$ at 135 MeV and 250 MeV are in a reasonable agreement with the data [3, 4] in forward hemisphere. The total hadronic polarized cross sections σ_1, σ_2, σ_3 are calculated using the generalized optical theorem as in [5]. In view of the planned accuracy of the $A_{y,xz}$ measurement of about 10^{-6} [1], the obtained numerical result for σ_1 put a strong restriction on the magnitude of the possible false vector polarization of the deuteron ($P_y < 10^{-6}$). Analytical formulas are derived for the $A_{y,xz}$ observable and its energy dependence is calculated for several types of phenomenological T-odd P-even NN-interactions. This dependence differs from that found in [6] where only a breakup mechanism was taken into account. We found that the ρ-meson exchange contribution to $A_{y,xz}$ vanishes and the Coulomb interaction does not lead to divergences for the $A_{y,xz}$ observable.

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THE DIFFERENTIAL CROSS SECTION IN THE dp-ELASTIC SCATTERING AT THE ENERGIES FROM 500 TO 1000 MeV/NUCLEON

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The results of measurements of dp-elastic scattering at energies between 500 and 1000 MeV/nucleon at Nuclotron JINR are reported. The data was obtained for angels range of 70-120 deg. in the c.m.s. The results are compared with existing data for respectively values of energies.

FUTURE USAGE OF QUASI-INFINITE DEPLETED URANIUM TARGET (BURAN) FOR BENCHMARK STUDIES

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The development of advanced nuclear systems needs reliable and accurate simulation codes. Significant necessity are benchmarks of Monte Carlo simulation programs (e.g. MCNPX), which are important for studies of neutron production, transport and transmutation of radioactive materials by produced neutrons. Experiments with different setups consisting of lead, natural uranium and graphite irradiated by relativistic protons and deuterons are used for such purposes at JINR Dubna. Experiments with new setup called „Buran“ should start soon. Preliminary calculations (in MCNPX code) of proton and deuteron beam transport through this setup and neutron production and fluxes in different places of such setup have been made. Representative results will be shown and discussed.

SELF-SIMILARITY OF PROTON SPIN

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Origin of spin is one of fundamental mysteries of nature. Spin of proton itself and of point-like quarks is equal to $1/2\hbar$. Composition of the proton spin from spins of the quarks, gluons and processes including formation and annihilation of the quark-antiquark pairs indicate on a repeated pattern in the proton internal spin structure over a wide scale range. The hypothesis of self-similarity of the spin structure is discussed. The concept of z-scaling previously developed for analysis of inclusive reactions is applied for description of processes with polarized particles. Generalized characteristics of the proton spin structure, namely spin-dependent fractal dimensions, are suggested. Possibilities of extracting information on these quantities from double spin asymmetries are discussed. New high-precision RHIC data on the asymmetries in polarized pp collisions are analyzed in the framework of the z-scaling. Information on spin-dependent fractal dimensions of proton is obtained. A microscopic scenario of constituent interactions developed within the z-scaling approach is used for study of the interactions with polarized protons. Spin dependence of the constituent energy loss as a function of the momentum of the produced hadron and the energy of collision is estimated.

LIGHT MESON EMISSION IN (ANTI)PROTON INDUCED REACTIONS

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Reactions induced by high energy antiprotons on proton on nuclei are accompanied with large probability by the emission of a few mesons. Interesting phenomena can be observed and QCD tests can be performed, through the detection of one or more mesons.

The collinear emission from high energy (anti)proton beams of a hard pion or vector meson, can be calculated similarly to the emission of a hard photon from an electron [1]. This is a well known process in QED, and it is called the "Quasi-Real Electron method", where the incident particle is an electron and a hard photon is emitted leaving an 'almost on shell' electron impinging on the target [2].

Such process is well known as Initial State Emission (ISR) method of scanning over incident energy, and can be used, in the hadron case, to produce different kind of particles in similar kinematical conditions.

In case of emission of a charged light meson, π or ρ-meson, in proton-proton(anti-proton) collisions, the meson can be deviated in a magnetic field and detected.

The collinear emission (along the beam direction) of a charged meson may be used to produce high energy (anti)neutron beams. This can be very useful to measure the difference of the cross sections of (anti)proton and (anti)neutron scattering from the target and may open the way for checking sum rules with antiparticles. Hard meson emission allows also to enhance the cross section when the energy loss from one of the incident particles lowers the total energy up to the mass of a resonance.

The cross section can be calculated, on the basis of factorized formulas, where the probability of emission of the light mesons multiplies the cross section of the sub-process. Multiplicity distributions for neutral and charged meson production are also given.

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ARE NARROW UNFLAVOURED MESONS A SIGNATURE OF NEW PHYSICS?

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Experimental works have been dedicated to the study of narrow, weakly excited, low mass unflavoured mesons [1]. Besides these works, a large number of data, studied for different purposes, exhibit also small structures in their spectra. These structures are observed in leptonic, as well as in hadronic reactions, but they were not discussed by the authors in detail.

However, when publishing the dedicated experiments quoted above, some of these structures were indicated, and the masses collected and discussed in different publications.

The present work collects data from dedicated - or not - experiments, and shows also old data never used to support the existence of narrow mesons. Evidence for narrow structures seen in the projection of a selected part of the scatterplot from $\bar{p}p$ annihilation at rest into two gammas: $M(\gamma 3, \gamma 4) = f\,(M(\gamma 1, \gamma 2))$ from Ref. [2] is reported for the first time.

The nice concordance of all various masses, strengthen the opinion that they are genuine. When their existence is clearly confirmed, the underlined physics remains to be clarified. We suggest tentatively to associate these findings to low masses produced by two quark clusters, similarly to models used to describe meson masses larger than 1.5 GeV. Indeed a very simple mass formula allows to get the experimental masses with only one relation and one parameter.

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CHARMONIUM PRODUCTION IN HEAVY ION COLLISIONS AND SUGGESTION OF NEW EXPERIMENTS ON FIXED TARGET

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The experimental data on charmonium states production measured at the CERN SPS and in p-p, p-Pb and Pb-Pb collisions at LHC and comparison with the data obtained at the Brookhaven Relativistic Heavy Ion Collider RHIC are presented. The suppression of J/ψ production was suggested as a possible signal of quark gluon plasma formation. The anomalous suppression of J/ψ production at the CERN SPS was discovered in central Pb-Pb collisions by NA50 collaboration at 158 GeV. But the effects of J/ψ suppression on cold nuclear matter and feed- down production from higher charmonium states are important in production of J/ψ. The PHENIX experiment at RHIC shows that the J/ψ suppression is of the same order at different energies from $\sqrt{s} = 200$ GeV to 39 GeV for different A-A systems. This J/ψ suppression is the same as the suppression at SPS energies for Pb-Pb as a function of multiplicity. At LHC the suppression is lower than at RHIC. The study of charmonium production at LHC shows the importance of regeneration process. At low transverse momentum large part of J/ψ are produced with regeneration, but at high transverse momentum contribution of regeneration is negligible. The J/ψ production from B-decay should be taken into account at LHC energy. The cold nuclear matter effects were measured in p-Pb collisions at LHC. These data were used as reference for investigation of J/ψ suppression in Pb-Pb collisions. At low transverse momentum J/ψ are produced with the enhancement in agreement with regeneration model. At high transverse momentum strong suppression is seen as indication on possible Quark Gluon Plasma formation. It is important to study the mechanism of quarkonium production and suppression at low energies up to 35 GeV/per nucleon (SIS300) at the FAIR in CBM and at NICA collider in Dubna with high statistic. The future measurements at fixed target at SPS and RHIC with high luminosity and statistic could investigate the properties of matter at high energy density and temperature. If the proton and ion beams will be used at LHC with fixed target, the energy interval between SPS and RHIC in p-A and A-A collisions could be investigated in order to measure medium effects and conditions for Quark Gluon Plasma formation.

RELATIVISTIC CORRECTIONS TO THE PAIR B_c MESONS PRODUCTION IN PROTON–PROTON COLLISIONS

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The necessity for consideration of relativistic corrections to processes of pair charmonium production was explicitly demonstrated on the example of $e^+e^- \to J/\psi+\eta_c$ process, which cross section was measured by Belle and BaBar collaborations in 2002–2005. The first experimental results appeared to be in serious disagreement with earlier theoretical predictions, carried out in leading order of strong coupling constant α_s as well as of heavy quark velocity v in the framework of nonrelativistic quantum chromodynamics (NRQCD) approach. The consequential calculation of several sorts of corrections, including an account of relativistic effects caused by the relative motion of constituent quarks and antiquarks in meson, has finally reduced the discrepancy.

In this work we present the calculation of relativistic corrections to the processes of pair B_c mesons production in proton–proton interaction. On the basis of perturbative QCD and relativistic quark model several types of corrections are considered. Relativistic terms in the production amplitude connected with the relative motion of heavy quarks and the transformation law of the bound state wave functions to the reference frame of moving mesons are taken into account. For the gluon and quark propagators entering the amplitude a truncated expansion in relative quark momenta is used. Relativistic corrections to the quark bound state wave functions are considered by means of the Breit-like potential. The numerical results for cross sections are obtained at the LHC relative energies $\sqrt{S} = 7$ and 14 TeV. It turns out that the examined effects significantly change the nonrelativistic predictions for the cross sections.

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MULTIFRAGMENT BREAK-UP OF ^{12}C IN PHOTONUCLEAR REACTIONS

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Disintegration of ^{12}C nuclei by tagged photons of 700–1500 MeV energy at the GRAAL facility has been studied by means of the LAGRANGE detector with a wide angulare acceptance. The energy and momentum distributions of neutrons and charged nuclear fragments as well as their multiplicity distributions were measured and compared with corresponding distributions calculated with the RELDIS model based on the intranuclear cascade and Fermi break-up models. It was found that 8 fragments are created on average once per 100 disintegration events, while a complete fragmentation of ^{12}C into 12 nucleons is observed typically only once per 5000 events. Measured muliplicity distributions of produced fragments are well described by the model. The total photoabsorption cross section on ^{12}C was also measured in the same energy range.

POLARIZED DEUTERON CHARGE-EXCHANGE REACTION $dp \to \{pp\}_s N\pi$ IN THE Δ-ISOBAR REGION

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The $dp \to \{pp\}_s n$ reaction at low momentum transfer from the incident deuteron to the final diproton $\{pp\}_s$ is sensitive to the spin-flip part of the nucleon-nucleon charge-exchange forces [1]. Here $\{pp\}_s$ is a pp pair at very low excitation energy, typically $E_{pp} < 3$ MeV, where it is predominantly in the $^1S_0$ state. A systematic study of this reaction had been started at ANKE@COSY in both single and double-polarized experiments. In addition to the $pn \to np$ subrporocess, there are variants of this reaction, namely $dp \to \{pp\}_s n\pi^0$ part of the or $dp \to \{pp\}_s p\pi^-$, that involve the spin-flip of the $pn \to \Delta^+(1232)n$ transition, which is difficult to measure directly.

Mechanisms of the charge-exchange reaction $dp \to \{pp\}_s N\pi$ are studied at beam energies 1-2 GeV, where the invariant mass of M_X of the final $N\pi$ system corresponds to the formation of the $\Delta^+(1232)$ isobar. The direct mechanism, where the initial proton is excited into $\Delta^+(1232)$, dominates and explains the existing data on the unpolarized differential cross section and spherical tensor analyzing power T_{22} for $M_X > 1.2\,GeV/c^2$ obtained at ANKE@COSY [2]. However, this model fails to describe T_{20} and possible reasons for this are discussed. In particular, parameters of the $\rho-$ meson contribution are varied. Possible connection with the old T_{20} puzzle [3] observed in deuteron-proton backward elastic scattering and $dp \to p(0)X$ disintegration are discussed.

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THEORETICAL DESCRIPTION OF THE FORWARD-BACKWARD MULTIPLICITY CORRELATIONS IN WINDOWS SEPARATED IN AZIMUTH AND RAPIDITY

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The forward-backward (FB) correlations between multiplicities in windows separated in rapidity and azimuth are analyzed in the framework of the model with strings as independent identical sources [1, 2]. Both the short-range (SR) contribution, originating from the correlation between multiplicities produced by a single source, and the long-range (LR) contribution, originating from the fluctuation in the number of strings [3], are taken into account. The dependencies of the FB correlation coefficient, b, on rapidity and azimuthal acceptance of windows and on corresponding gaps between them are studied and compared with the experimental data [4]. It is demonstrated that the analysis of these dependencies enables to separate the contributions of two above mechanisms [5].

It is also shown that the presence of the SR pair correlations between particles produced by one string, along with the influence on the FB multiplicity correlation, inevitably turns strings into non-poissonian sources. Whereas the LR correlations provide the information on the scaled event-by-event variance of the number of the sources, which is also non-poisson in both pp and AA collisions [6]. It is found that the traditionally defined b has the strong nonlinear dependence on the acceptance of the windows, hence the results obtained from windows of different widths cannot be compared directly. In this connection, the suitable observables for the future FB correlation studies are proposed.

The connection of the b with the two-particle correlation function C_2 and the untriggered di-hadron correlation analysis is also traced. Using a model independent analysis, it is shown that the measurements of the FB correlations between multiplicities in two small windows separated in rapidity and azimuth enable to find the two-particle correlation function C_2 even if the particle distribution in rapidity is not flat (as e.g. in the case of pA interactions) and the C_2 does not only depend on the differences of rapidities.

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MEASUREMENT OF THE DIFFERENTIAL CROSS SECTIONS OF THE PROCESSES WITH A DIRECT PHOTON AND ASSOCIATED HADRONIC JET IN $p\bar{p}$ COLLISIONS AT $\sqrt{s} = 1.96$ TeV

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The process $p\bar{p} \to \gamma + \text{jet} + X$ is studied using 8.7 fb^{-1} of integrated luminosity collected by the D0 detector at the Fermilab Tevatron Collider at a center-of-mass energy $\sqrt{s} = 1.96$ TeV. Photons are reconstructed with rapidities $|y^\gamma| < 1.0$ or $1.5 < |y^\gamma| < 2.5$ and transverse momentum $p_T^\gamma > 20$ GeV. The highest-p_T jet is required to be in one of four rapidity regions up to $|y^{\text{jet}}| \leq 3.2$. The triple differential cross sections $\mathrm{d}^3\sigma/\mathrm{d}p_T^\gamma \mathrm{d}y^\gamma \mathrm{d}y^{\text{jet}}$ are measured as a function of p_T^γ separately for events with the same sign ($y^\gamma y^{\text{jet}} > 0$) and opposite sign ($y^\gamma y^{\text{jet}} \leq 0$) of photon and jet rapidities. Results are compared with next-to-leading order (NLO) perturbative QCD calculations using different sets of parton distribution functions and to predictions from the SHERPA and PYTHIA Monte Carlo event generators. The NLO calculations are found to be in general agreement with the data, but do not describe all kinematic regions.

NUCLEAR DATA FOR ADVANCED NUCLEAR SYSTEMS

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The development of advanced nuclear systems as generation IV reactors, accelerator driven systems and fusion reactors need new reliable high-quality nuclear data. Mainly complete and accurate information about the nuclear reactions taking place in the mentioned nuclear projects is essential. Description of neutron transport and transmutation of actinides or fission products by neutrons need precise information about neutron reactions cross-sections. Additional experimental measurements and their analysis are needed in a broad range of neutron energies and materials. Different types of white and quasi-monoenergetic neutron sources are possible to use for such studies.

Our utilization of two neutron sources for studies of neutron reaction cross-sections on broad range of materials can be example of such measurements. The first facility is the neutron source based on the cyclotron at the Nuclear Physics Institute of ASCR, Řež. It provides neutron beams in the energy range from 14 MeV up to 35 MeV. The second neutron source is built around the cyclotron at TSL Uppsala. This facility provides neutron beam in the energy range from 14 MeV up to 200 MeV. We have studied cross-sections of neutron reactions on gold, aluminum, bismuth, cobalt, iron, copper, zinc, yttrium and other materials. We have analyzed even population of ground and isomeric states separately. These are not only potential construction materials but also materials usable for activation detectors.

Both sources are part of the CHANDA (solving CHAllenges in Nuclear DAta for the safety of European nuclear facilities) project within 7$^{\text{th}}$ Euroatom Fission Framework Programme. This project is continuation of the ERINDA project with main goal to open European neutron facilities to European users. First call for proposals was evaluated few weeks ago. Very interesting results were obtained within the previous project ERINDA.

The obtained data are very important also for our collaboration Energy and Transmutation of Radioactive Waste which uses different setups consisting of lead, natural uranium and graphite irradiated with relativistic protons and deuterons to study transmutation of radioactive materials by produced neutrons. The collaboration uses activation samples to provide not only mapping of neutron flux inside setups but also to determine integral of proton or deuteron beams. This was the reason why we carried out series of experiments devoted to determination of deuteron reactions on copper using Nuclotron of JINR Dubna irradiations. The Nuclotron and Phasotrons beams are excellent tool for various important cross-section measurements.

FEASIBILITY STUDY OF Φ (1020) PRODUCTION AT NICA/MPD

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The goal of this report is to provide an overview of the MultiPurpose Detector (MPD) at NICA and to present the current results of the MPD performance for ϕ-meson production.

The Nuclotron-based Ion Collider fAcility (NICA) is a new accelerator complex being constructed at JINR. The global scientific goal of the NICA/MPD project is to explore the phase diagram of strongly interacting matter in the region of highly compressed baryonic matter. The MPD detector covers a large phase space, it is functional at high interaction rates and comprises high efficiency and excellent particle identification capabilities.

Measurements of the production of strange particles such as the ϕ-meson can provide important information on the properties of the medium and particle production mechanisms in ultra-relativistic Au-Au collisions. The ϕ vector meson is the lightest bound state of hidden strangeness, consisting of a quark-antiquark pair. The ϕ-meson has a very small cross-section for interactions with non-strange hadrons and a relatively long life-time of ~ 46 fm/c. These properties make the ϕ-meson an excellent probe of the hot and dense medium created in nucleus-nucleus collisions at NICA/MPD.

In this report methods for calculating the invariant mass of the ϕ-meson are presented, measurements of the combinatorial background and its rescaling are shown and fitting by a Breit-Wigner function is performed.

In our study we use the channel decay $\Phi \to K^+K^-$ to detect the formation of the ϕ-meson. UrQMD event generator is used and central events at $\sqrt{s} = 11$ GeV are analyzed. The invariant mass of the kaon pairs is calculated and then the combinatorial background (mixed-event technique) is subtracted. The obtained peak from the invariant mass distribution is fitted by a Breit-Wigner function and the characteristics of the ϕ-meson such as its mass and its width are found. The values of the parameters obtained by the fit are consistent with the values given in literature. This study shows that the measurement of ϕ-mesons at NICA/MPD is feasible.

PHASE TRANSITION IN MULTICOMPONENT FIELD THEORY AT FINITE TEMPERATURE

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In hot and dense nuclear matter, there can exist several phase transitions, such as deconfinement of hadron matter into quark–gluon plasma, hadron liquid–gas transition, nuclear superfluid transition, and colour superconducting transition. Such transitions can be observed in heavy–ion collisions. For characterizing phase transitions, one employs either effective mean-field models, or lattice simulations, or some kind of perturbation theory in the frame of a microscopic approach. The use of perturbation theory is practically always complicated because of the absence of small expansion parameters, which yields divergent series. In the present report, we describe the approach allowing for an accurate consideration of phase transitions, which is based on optimized perturbation theory and self-similar approximation theory. The illustration is given by the example of symmetry breaking in multicomponent field theory.

CUMULATIVE PROTONS IN HADRON-NUCLEUS AND NUCLEUS-NUCLEUS INTERACTIONS AT HIGH ENERGIES

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The data on the production of cumulative protons in interactions of hadrons and relativistic nuclei with nuclei in the primary energy range 3 – 300 GeV are presented. The obtained data demonstrate a universality of multiplicity and spectra of cumulative protons.

THREE-NUCLEON CALCULATIONS WITHIN THE BETHE-SALPETER APPROACH WITH SEPARABLE KERNEL

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We investigate the relativistic properties of the three-nucleon bound system. We used covariant Bethe-Salpeter (BS) approach to achieve the goal. The relativistic analog of the Faddeev equation are considered in the BS formalism.

The nucleon-nucleon kernel is chosen to be in the separable form (rank I)

$$V(p_0,p,p_0^{'},p^{'})=\lambda g(p_0,p)g(p_0^{'},p^{'})$$

In this case the two-particle T matrix has the following form

$$T(p_0,p,p_0^{'},p^{'};s)=\tau(s)g(p_0,p)g(p_0^{'},p^{'})$$

where

$$\tau(s)=[\frac{1}{\lambda}-\frac{i}{4\pi^3}\int_{-\infty}^{\infty}dk^0\int_0^{\infty}k^2dkg^2(k^0,k)G(k^0,k;s)]^{-1}$$

and g is the form factor. We consider covariant relativistic Yamaguchi-type functions for the form factors:

$$g_Y(p_0,p)=\frac{1}{-p_0^2+p^2+\beta^2}.$$

In this case the system of the integral equations for the three-nucleon wave function has the following form

$$\Phi_j(q_4,q)=-\frac{1}{4\pi^3}\sum_{j^{'}=1}^{2}\int_{-\infty}^{\infty}dq_4^{'}\int_0^{\infty}q^{'2}dq^{'}Z_{jj^{'}}(iq_4,q;iq_4^{'},q^{'};s)\frac{\tau_{j^{'}}[(\frac{2}{3}\sqrt{s}+iq_4^{'})^2-q^{'2}]}{(\frac{1}{3}\sqrt{s}-iq_4^{'})^2-q^{'2}-m^2}\Phi_{j^{'}}(q_4^{'},q^{'}),$$

where j=$^1S_0$,$^3S_1$, and Z is the so-called effective energy-dependent potential

$$Z_{jj^{'}}(iq_4,q;iq_4^{'},q^{'};s)=C_{jj^{'}}\int_{-1}^{1}d(cos\vartheta_{qq^{'}})\frac{g_j(-\frac{1}{2}q^0-q^{0^{'}},|\frac{1}{2}\mathbf{q}+\mathbf{q}^{'}|)g_j(q^0+\frac{1}{2}q^{0^{'}},|\mathbf{q}+\frac{1}{2}\mathbf{q}^{'}|)}{(\frac{1}{3}\sqrt{s}+q^0+q^{0^{'}})^2-(|\mathbf{q}+\mathbf{q}^{'}|)^2-m^2},$$

with $C_{jj^{'}}$ is spin and isospin recoupling-coefficient matrix.

To solve the system of integral equations the Gaussian quadrature method is used. The mappings for the variable of integration $[0,\infty)$ and $(-\infty,\infty)$ to $[-1,1]$ interval are used. The considered quadrature system allows to transfer the homogeneous system of integral equations to linear algebraic equations which can be solved using the programming language FORTRAN.

In the report the results for the $^1S_0$ and $^3S_1$ waves in the three-nucleon bound state wave-function are considered on the q_4 and q variables.

EXOPLANETARY SEARCHES WITH GRAVITATIONAL MICROLENSING: POLARIZATION ASPECTS

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There are different methods for finding exoplanets such as radial spectral shifts, astrometrical measurements, transits, timing etc. Gravitational microlensing (including pixel-lensing) is among the most promising techniques with the potentiality of detecting Earth-like planets at distances about a few astronomical units from their host star or near the so-called snow line with a temperature in the range $0 - 100^0$ C on a solid surface of an exoplanet. We emphasize the importance of polarization measurements which can help to resolve degeneracies in theoretical models. In particular, the polarization angle could give additional information about the relative position of the lens with respect to the source.

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REACTION RATES OF RESIDUAL NUCLEI PRODUCED IN ^{59}Co WITH THE SPALATION NEUTRONS GENERATED WITH DEUTERONS OF ENERGY 4 AGeV AT THE MASSIVE URANIUM TARGET QUINTA

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The experimental samples of ^{59}Co (1 mm thick and mass of ~ 1 g) have been irradiated in the field of secondary neutrons generated at the massive natural uranium spallation target QUINTA. The target assembly consists of five hexagonal sections composed of cylinders made of natural uranium of the total mass of 512 kg. The target was irradiated with deuteron beams at the JINR Nuclotron accelerator in December 2013. The experimental results on the 4 AGeV deuteron beam are presented in this work. The total flux of deuterons on target was N d = 6.11(8)E+12 particles during the 1638 min irradiation. Ten cobalt experimental samples were situated in different position along the target axis (z = 254; 385; 516; 647 mm) and target radius (r =0; 40; 80; 120 mm).

After the irradiation, the experimental samples were transported to the YaSNAPP spectroscopy laboratory and measured with the use of HPGe detectors. Each sample was measured approx. three times. The reaction rates (R, the number of produced residual nuclei per one deuteron and one atom of the sample) were obtained for the following reaction products: ^{46,47,48}Sc, ^{48}V, ^{51}Cr, ^{52,54}Mn, ^{56,57,58}Co, ^{59}Fe and ^{60}Co. The experimental reaction rates were compared with calculated reaction rates - convolution of the neutron flux simulated with the MCNPX 2.7 code and the cross-section data extracted from the TENDL-2012 data library and the TALYS 1.6 code).