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A structure of atomic nuclei have many examples of a phase transitions with increase of the excitation energy, rotational moment and changing of the number of nucleons. These are phase transitions in the equilibrium shape and structure of the ground and low-lying excited states related to symmetry changed. The problem of phase transitions has caused of new wave of researches of the structure of atomic nuclei. In the review are considered different examples of nuclear phase transitions. Description of phase transitions in collective nuclear model and microscopic aspects of phase transitions are discussed.

RECENT RESULTS FROM NA61/SHINE STRONG INTERACTION PROGRAMME

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The research programme of the NA61/SHINE Collaboration covers a wide range of hadronic physics in the CERN SPS energy range (beam momentum $13A$ - $158A$ GeV/c), encompassing measurements of hadron-hadron, hadron-nucleus as well as nucleus-nucleus collisions. Data are analysed to better understand the properties of hot and dense nuclear matter. This talk will present the energy dependence of quantities inspired by the Statistical Model of Early Stage (kink, horn and step) as well as recent results of particle production properties in p+p and centrality selected Be+Be, Ar+Sc at the SPS energies. Moreover, the current achievements and future plans related to the measurement of open charm production will be presented.

NEW NUCLEAR PHYSICAL PHENOMENON - SPONTANEOUS NUCLEAR SYNTHESIS

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For the first time, a new nuclear-physical phenomenon is described - the flight out from complex nuclei of the lightest clusters with mass numbers from 1 to 4. The interpretation of the phenomenon consists in the assertion that the multiclusters recently experimentally discovered in the volume of nuclei [1] spontaneously enter into thermonuclear fusion reactions with each other. While they have the indicated lightest clusters with noticeable kinetic energies in the output channels.
Until now, only the spontaneous fission of nuclei discovered in 1940 by Petrzhak K.A. and Flerov G.N. and alpha-decays were known. An experimental search for spontaneous fusion of nuclei was not carried out, first of all, due to the lack of physically reasonable initial premises. Currently, such

physical conditions have arisen in connection with the experimental discovery in the volume of nuclei of spatially separated clumps of nuclear matter — multiclusters with mass numbers A = 1, 2, 3, 4 [1] and measurements of their cluster widths.
In fact, with an asymptotic giant mean density of nuclear matter of 0.147 Fm^{^(-3)}, it turned out that spatial clusters coexist in the volume of complex nuclei in the form of deuterons (d), tritons (t), helium-3 nuclei (h) and helium-4 nuclei (α) [2]. Naturally, this gives rise to a noticeable probability of their fusion in various combinations, including exothermic ones, which in modern terminology can be described as the implementation of “spontaneous thermonuclear fusion” in the solid phase of a substance. Note that until now they are trying to carry out controlled thermonuclear fusion only in the gas-plasma phase, for example, in installations of the Tokamak type.
In this work, the calculation of the spectra of spontaneous thermonuclear particles emitted as a result of spontaneous nuclear fusion between multiclusters inside the volume of complex nucleus was performed under the condition that the effective number of clusters (multicluster widths), which are given in [1], are equal. Theoretical spectra of spontaneous intranuclear synthesis for gamma quanta, neutrons, protons, deuterons, tritons, helions, alpha ions (intranuclear α-particles) and heavy ions are calculated. The calculated spectra contain only high-energy components for each output channel, without taking into account the loss of their energy in nuclear matter inside the nucleus volume. Comparison with experiment shows satisfactory agreement. It should be noted that in the world literature there is no information about the search for deuteron, triton and helion radioactivity of complex nuclei. Therefore, these sections of the physics of stable and radioactive nuclei are relevant for research.

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NUCLEAR PHYSICS IN MEDICINE: PRESENT AND PROSPECTS

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Modern medicine has a large arsenal of equipment for diagnostic and therapeutic purposes, which uses sources of ionizing radiation - these are x-ray tubes, natural and artificial isotopes, accelerators. The science of physical radiation and devices, medical diagnostic devices, facilities and technologies, the ability to diagnose and treat diseases of the human body using methods and means of physics, mathematics and technology is called medical physics.
Modern medical physics includes a number of major areas of application of physical methods in medicine: physics of remote and contact radiation therapy, nuclear medicine, radiation diagnostics, physics of non-ionizing methods of diagnosis and therapy and radiation safety.
A coordinated interaction between a doctor and a medical physicist is necessary for successful work on radiation treatment of patients.
Very specific and deep training requires for successful work of such a specialist in the field of radiation therapy.
The training in the educational program of professional retraining of specialists in the field

The mechanisms for the formation of cross sections for elastic scattering of heavy ions on light nuclei remain controversial and require more detailed studies. In the differential cross sections of earlier papers [1], weak oscillations are observed in the region of small and medium angles, while in the backscattering angles they manifest themselves quite sharply, and with increasing energy of the incident ion, the oscillations increase. A noticeable increase in cross sections in the region of large angles is also observed. Such a behavior of the angular distributions of elastic scattering of heavy ions is difficult to theoretical description within the framework of the standard optical model. It follows from this that, in addition to the purely potential interaction, other mechanisms that must be taken into account in theoretical analysis contribute to the formation of elastic scattering cross sections in these processes. In particular, it is necessary to take into account the cluster structure of the studied nuclei and the mechanisms of cluster transfer.
At the DC-60 accelerator of the Institute of Nuclear Physics (Nur-Sultan, Kazakhstan), differential cross sections of elastic scattering of ^{14}N ions on ^{16}O nuclei were measured at energies of 1.5 and 1.75 MeV/nucleon in the range of angles 30^0–165^0 in the center of mass system [1].
The analysis of angular distributions at energies of 21–76.2 MeV was carried out in the framework of the optical model and the distorted wave Born approximation (DWBA) methods using the FRESCO program. It should also be noted that we introduced two additional potentials in a phenomenological way, exploring the sensitivity of scattering to the optical potential. In the framework of the DWBA, elastic scattering was analyzed taking into account the contribution of the cluster transfer mechanism, which showed that for ^{16}O(^{14}N,^{16}O)^{14}N processes in the region of large angles, the influence of this mechanism on the formation of scattering cross sections is significant.

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UNIQUE CORRELATION OF QUADRUPOLE DEFORMATION OF NUCLEI WITH THEIR HALF-LIVES

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The problem of halo nuclei [1] in a detailed analysis of sizes and deformations in isotopic series reveals not abrupt behavior in the topology of nuclei, but a sequential continuous change in the structural nuclear parameters as they move away from the axis of the "Line of stability". This suggests the inevitable correlation of structural isotopic parameters with electromagnetic and purely nuclear [2].
In the this work, this phenomenon is traced by the example of isotopic series of Barium and Xenon, in which, as in the previous study [2], it was possible to find a correlation between the parameter $\beta 2$ and half-life T1/2 for oblate nuclei with signβ2<0 and anti-correlation for elongated nuclei signβ2>0. Using the found analytical expressions for the function β2(T1/2) in these isotopic series, it is possible to semi-empirically approach the boundary of the bound states of nucleon systems both from the side of neutron-deficient nuclei and from the side of neutron-rich ones, which is an independent fundamental problem. These relations make it possible to calculate quadrupole deformation parameters $\beta 2$ from the usually measured half-lives T1/2 with high accuracy (from 5 to 10%), and through them the average radii of exotic nuclei $< R >$. Of particular interest is the possibility of extending this pattern to the region of superheavy nuclei. This method is a new way of assessing the Z-region, in which, probably, the maximum of the "Island of stability" is located.
In addition, when considering isotopic changes in the radii of nuclei in the present work, it can be seen that if the law of growth of radii, based on the growth of their masses $< R >= r_0 A^{1/3}$ (or for isotopic series $< R >= r_0 N^{1/3}$) is well observed in the direction of neutron excess, then this law is broken in the direction of neutron deficiency due to Coulomb repulsion of protons. And, as the

mass number A decreases, it does not lead to a decrease in their radii, but, on the contrary, to their growth. This effect apparently allows for the first time to ascertain the experimental detection of void nuclei.

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FORMATION OF INCLUSIVE REACTION SPECTRA (p, xd) ON MIDDLE CORES

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The development of the concept of the mechanism of pre-equilibrium decay in nuclear reactions, reflecting the dynamics of the formation and evolution of an excited system to an equilibrium state, remains an urgent task of the theory of nuclear reactions [1] To a large extent, its solution is connected with the need to obtain precision experimental data that are currently missing for double differential cross sections in reactions with charged particles.

The experimental measurements of the double-differential reaction cross sections (p, xd) were carried out on a beam of accelerated protons with an energy of 30 MeV of the isochronous cyclotron U-150 M INP using self-sustaining targets. The measurements were performed in the angular range of 30-135° in the laboratory coordinate system with a step of 15°.

The systematic errors in the cross sections were mainly caused by errors in the determination of the target thickness (<5%), calibration of the current integrator (1%), and solid angle of the spectrometer (1.3%). The energy of a beam of accelerated particles was measured with an accuracy of 1.2%. The total systematic error did not exceed 10%. The statistical error varied for deuterons from 5% in the low-energy to 20% in the high-energy energy regions. After integration over the angle of the double-differential cross sections, integral cross sections of these reactions were obtained.

The analysis of the experimental results was carried out in the framework of the Griffin exciton model [2] of pre-equilibrium nuclear decay according to the PRECO-2006 program [3], which describes the emission of particles with mass numbers from 1 to 4. Satisfactory agreement was obtained between the experimental and calculated values in the energy region corresponding to the pre-equilibrium mechanism.

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CHARGE DIPOLE POLARIZATION IN ULTRAMAGNETIZED NUCLEI

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Properties of ultramagnetized atomic nuclei relevant for supernovae, neutron star mergers, magnetar crusts and heavy-ion collisions are analyzed. Nuclear magnetic reactivity of Zeeman type is shown to dominate for field strengths below ten teratesla. Respective linear magnetic response is given as a combined reactivity of valent (outer shell) nucleons and can be described in terms of nuclear magnetic susceptibility. Valent protons and neutrons occupy [1] orbitals with minimum and maximum spin projection on a field axis, respectively. Consequently, charged (protons) and neutral (neutrons) nucleons are spatially separated. Effects of such charge dipole polarization in nuclear reactions are discussed.

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INTRANUCLEAR CASCADES EFFECTS ON THE COMPOSITION AND ENERGY OF (p,x)-NUCLEAR REACTION PRODUCTS

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The relaxation of the nucleus in the pre-equilibrium phase, excited in reaction with protons of high energy, proceeds predominantly via an emission of several nucleons and α-particles. In addition to light nuclei with Z ≤ 2 and neutrons at the proton energies E0 > 140 MeV, γ quanta, leptons, and mesons there can also be emitted. The charge, mass, and energy distributions of heavy fragments formed in the collisions of protons with silicon and iron nucleus are studied using TALYS-1.9 [1], GEANT4 [2] and FLUKA [3] programs. The divergence between TALYS and GEANT4, FLUKA results above 300 MeV is analyzed and ascribed to the contribution of intranuclear cascades developed in the p+Si and p+Fe nuclear systems which is taken into account in GEANT4 and FLUKA, but not in TALYS. From the comparison, we deduce the essential role of intranuclear cascades in the compound p+Si and p+Fe nuclear systems at the pre-equilibrium phase of reaction at high colliding energies.

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ELECTROMAGNETIC INTERACTIONS IN THE VOLUME OF NUCLEI

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Structuring the volumes of nuclei and the complex topology of their surfaces, along with attractive nuclear forces, in certain conditions, electromagnetic forces manifest themselves more significantly. At the line of the stability path of exotic nuclides, these forces begin to prevail.
In this paper, we describe the mechanism of interaction of nucleons in the nucleus volume as the interaction of dipole-dipole intranuclear clusters. Such an interaction and its sign, first of all, will depend on the spatial orientation of nucleons or clusters in the nucleus and, therefore, the interaction potential of electromagnetic forces should include not only the Coulomb repulsion of charged nucleons (clusters) but also the magnetic component, which includes the spin-orbit the interaction of nuclear clusters $V = V_c + V_m(sl)$, where V_c is the Coulomb potential; $V_m(sl)$ is the potential of the dipole-dipole interaction. The magnetic component of the electromagnetic potential depends both on the total spin of the nuclear clusters and on their spatial position (orbital). This paper considers nucleons and nuclear clusters that form in dipoles. Based on experimental data on the elastic scattering of alpha particles by ^{24}Mg from the found cluster widths for mass numbers from 1 to 4 [2], it was possible to construct the corresponding dipole – dipole interaction in s, p, and d states. In the field of heavy nuclei, neutron-deficient and neutron-rich isotopes, the density of nuclear matter fluctuates with respect to the constant 0.15 fm^{-3} [1]. This fluctuation is associated not only with the deformation of nuclei, but also with the spatial distribution of nucleons within the volume of the nucleus. With an increase in the mass number, the Coulomb repulsive forces cause protons and isolated nuclear clusters to move to the periphery of the nucleus, thereby abnormally increasing the average radius of the nucleus and its deformation, which should affect the density of nuclear matter. From the constructed isotonic dependences of the binding energy of nucleons in the nucleus on the proton excess and deficit, it can be seen that the binding energy per one nucleon decreases quadratically with a decrease and addition of each subsequent proton, which leads to inflation of the nucleus volume and, possibly, the formation of "bubble" nuclei that were still unsuccessfully tried to find in the experiment. Such an idea about inflating the volumes of nuclei was expressed to the authors by Oganessian Yu.T., who drew attention to a particularly significant effect in the field of "Island of stability".

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EXPLOSION OF LOW-MASS NEUTRON STAR IN CLOSE BINARY SYSTEM AND NUCLEOSYNTHESIS OF HEAVY ELEMENTS.

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First observation of neutron star merger and registration of heavy elements presence in this process [1] confirmed our understanding that main scenario for the r-process is connected with the ejecta during neutron star merger (NSM) at the end of close binary system evolution rather than with the supernova explosion [2].
A number of NSM model were created [3] since 1999 year and with their help the main conditions

CHARGE MEASUREMENTS OF EvRs IN EXPERIMENTS ON THE SYNTHESIS OF Ra AND Th ON A NEW GAS-FILLED SEPARATOR DGFRS-II

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Since 1998, experiments on the synthesis of superheavy elements (SHE) have been carried out at the Flerov Laboratory of Nuclear Reactions (FLNR) of the Joint Institute for Nuclear Research (JINR) on a gas-filled recoil separator (DGFRS). The heaviest element ^{294}Og with Z = 118 was registered in 2002, 2005, 2012 and 2015. In all these experiments, ^{48}Ca heavy ion beams accelerated at the *U-400* cyclotron were used. Further use of calcium ions as an incident projectile does not allow the synthesis of elements heavier than ^{294}Og, since there is no sufficiently stable target material. To conduct further studies of SHEs at the JINR FLNR, the SHE Factory based on the new *DC-280* cyclotron was created. Achieved beam intensity is 10 times higher than *U-400*. The first experimental setup of the SHE Factory is the new DGFRS-II which have configuration of QDQQD magnets (Q – quadrupole, D – dipole). The main feature of this setup is the high collection efficiency of synthesized superheavy nuclei, exceeds 60% for targets up to 0.5 mg/cm^2 thick, which is 2 times higher than DGFRS-I. In 2019, test experiments on the new separator were conducted. The main goal of this experiments was to determine the optimal parameters of the DGFRS-II separator: $^{170}Er +^{48} Ca{—}>^{214,215} Ra,^{nat}Yb,^{174}Yb +^{48} Ca{—}>^{216,217} Th.$

In this talk, results of this experiments are shown. For each experimental reaction charge of the synthetized nuclei were calculated together with dispersion on two main dipoles. Energy losses during evaporation residues transport were calculated as well.

MODELING OF THE DISTRIBUTION OF RADIONUCLIDE CONCENTRATIONS IN ORGANS AND TISSUES OF THE HUMAN BODY

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Monitoring the accumulated dose in the population from natural terrestrial radionuclides and timely assessment of the maximum dose to prevent potential risks of radiogenic oncological diseases is an important and one of the priority tasks. The main source of the accumulated dose by the population is the natural terrestrial radionuclides that enter the body through human life, and this problem is international in nature [1].

The concentration of chemical elements in the organs and tissues of the human body pretty much depends not only on the use of certain products, but also on geographical residence with a different geological landscape [2]. Different concentrations of chemical elements accumulated in various organs or tissues entail the accumulation and corresponding distribution of natural radionuclides. In this work, the authors developed a software-mathematical complex [3], which allows you to simulate the distribution of natural nuclides and radionuclides in the organs and tissues of the human body. Unlike existing software systems that simulate the interaction of radiation with biological objects, such as Geant4-DNA, etc. [4], the developed program simulates the spread of radionuclides throughout the body, taking into account the conversion factors from one organ to another. Thus, a mathematical calculation based on experimental accumulation coefficients and methods for calculating the doses of ICRP makes it possible to calculate the internal radiation doses of the corresponding

organs and tissues. Such modeling allows us to calculate the risks of cancer due to internal exposure to incoming natural terrestrial radionuclides. The distribution of the studied radionuclides is visualized, which allows you to visually study the potential areas of internal sources of radioactive radiation.
The result of the development of this software was the collective work of a team of authors, which was carried out in an open-type nano-technological laboratory at KazNU al-Farabi from 2018 to 2020. with the support of state grant funding for basic research (project: "Fundamental research on the mechanisms of formation of nanoscale oncradiogenic structures in the body and the development of anti-cancer rapid devices for their detection", No. IRN AP05131884).

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STUDY OF THE INTERACTION TRIGGER AND BEAM ION FRAGMENTATION FOR Au + Au COLLISIONS IN BM@N EXPERIMENT

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The Monte-Carlo simulation of the trigger detector performance and interaction trigger efficiency for Au + Au collisions in BM@N[1-2] experiment at energy of $4A$ GeV was performed with a code DCM-QGSM[3] + GEANT4[4]. The Au ion fragmentation and detection of spectator neutrons by a neutron zero-degree calorimeter and charged nuclear fragments by a forward Cherenkov counter were studied with the aim to include this information to the fast interaction trigger providing more reliable selection of events by centrality.

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NEWBY SHIFTS IN ODD-ODD TRANSITIONAL NUCLEI AT A$\sim$190

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of the nuclei is $\lambda_n < 0$. These isotopes can be considered as neutron-stable. For the isotopes ^{70}Ca (forces UNEDF1) and ^{68}Ca (forces SLy4) in the vicinity of the min curve E(β_2), the chemical potential of the nuclei is $\lambda_n > 0$. If we consider the condition $\lambda_n < 0$ as a condition for the stability of the nucleus with respect to the emission of one neutron, then the nucleus ^{70}Ca (for forces UNEDF1) and ^{68}Ca (for SLy4 forces) cannot be considered as neutron-stable. In [3], these nuclei are given as neutron-stable for which the separation energies of one neutron have positive values.

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THE ELECTRONS AND GAMMA QUANTA SOURCE AT THE LUE-8-5 ACCELERATOR OF INR RAS FOR CALIBRATION OF NUCLEAR DETECTORS.

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A source of electrons and gamma quanta for nuclear detectors calibration is described. The source was developed on the basis of the LUE-8-5 electron accelerator of the INR RAS. The electrons energy is variable within 4 – 10 MeV. The energy resolution (FWHM) is better than 1%, the counting rate is of order of one particle per acceleration cycle. Repetition rate is up to 300 s-1. beam pulse duration of 3 μs, the duty cycle equals to 0.1%. The source consists of a stretching magneto-optical system and beam correction, collimation and cleaning systems. The source is provided by information storage and processing system.

METHODS FOR MEASURING DAUGHTER PRODUCTS OF RADON DECAY IN THE SURFACE ATMOSPHERIC LAYER OF THE EARTH

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Despite numerous studies of radon emanation [1-3], the problem of studying the distribution of radon concentrations in the surface atmospheric layer of the Earth is relevant. The contribution of radon and its daughter decay products to the general background radiation is large and amounts to more than 50%. Time of variations of radon emanation, studied by the authors of [4], showed its strong concentration dynamics not only from daily and seasonal variations, but also from other external factors. In addition to time of distributions, we and other authors have shown that radon and its daughter decay products are distributed in the surface atmospheric layer of the Earth both in a complex manner depending on the height inside the buildings and on the geological landscape [5]. We performed measurements with a spectrometric setup of beta spectra for the period from October 2018 to February 2020, from which it is clear that the integral values of the spectra of beta particles during the day strongly fluctuate relative to the average daily value. The mechanism of

such fluctuations may be the soft electron-photon component of the secondary cosmic radiation.
To measure the low-background beta radiation of various samples for the content of natural beta-radionuclides in the present work, the authors proposed a technique that will allow for taking into account events arising from other sources. Based on this technique, a spectrometric "telescope" was developed [6], in which, as protection against cosmic radiation, active protection was applied in the form of a second detector that detects external radiation, which is included in the anticoincidence scheme with the main detector. The opposite arrangement of the detectors on the vertical axis and in the lead glass of the main detector allows one to register events that occur in the local area of the space to which the telescope is oriented.
The work was supported by the state grant financing of basic research (project No. IRN AP05131884)

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INFLUENCE OF RELATIVISTIC NUCLEON DYNAMICS ON THE SCALAR QUARK CONDENSATE IN NUCLEAR MATTER

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The scalar quark condensate $\kappa(\rho) = \langle M|\sum_i \bar{q}_i q_i|M\rangle$ in nuclear matter can be presented as $\kappa(\rho) = \kappa(0) + \kappa_N\rho + S(\rho)$ with $\langle M|$ the ground state of the matter while q are the operators of the light quarks u and d. Here ρ is the density of the matters, $\kappa(0)$ is the vacuum value of the condensate. In the second term on the right hand side the matrix element κ_N is $\kappa_N = \langle N|\sum_i \bar{q}_i q_i|N\rangle$ with $\langle N|$ standing for the free nucleon at rest. This matrix element can be expressed in terms of the nucleon sigma term σ_N related to observables. The various experiments provide the values between 40 MeV and 65 MeV for σ_N. The first two terms in definition of $\kappa(\rho)$ compose the gas approximation.
The contribution $S(\rho)$ describes the change of $\kappa(\rho)$ caused by the nucleon interactions. It was demonstrated that $S(\rho)$ is due mostly to the pion cloud created by interacting nucleons (see [1] for references). In the latter calculations $S(\rho)$ was obtained employing the nonrelativistic approximation for nucleons of the matter (curve 1 in Fig. 1). The latest results obtained in framework of chiral perturbation theory [2] are shown by the curve 2.
In the present report the matter is viewed as a relativistic system of nucleons. In the first step we neglect their interactions. We find that the quark condensate can be presented as $\kappa(\rho) = \kappa(0) + \kappa_N\rho F(\rho, m^*(\rho))$ with $F(\rho, m^*(\rho)) = 2/(\pi^2\rho)\int_0^{p_F} dp\, p^2\, m^*/\sqrt{m^{*2}+p^2}$. Here p_F is the Fermi momentum, m^* is the nucleon Dirac effective mass. Note that the same function $F(\rho, m^*(\rho))$ connects the vector and scalar densities in the Walecka model.
The effective mass m^* can be calculated in a hadron model. In the version of QCD sum rules presented in [3] the right hand side of the scalar channel equation contains the effective mass $m^*(\rho)$ while the left hand side contains the scalar condensate $\kappa(\rho, m^*(\rho))$. Thus we come to self-consistent equation for $m^*(\rho)$ which was solved in [3]. Here we employ these results for calculation of $\kappa(\rho)$ (curve 3 in Fig. 1). One can see that inclusion of the relativistic dynamics of nucleons is as important as that of nucleon interactions.