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HADRONS FROM RELATIVISTIC QUARKS AND SPIN EFFECTS IN HIGH-ENERGY PROCESSES AT HIGH Q^2

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АДРОНЫ ИЗ РЕЛЯТИВИСТСКИХ КВАРКОВ И СПИНОВЫЕ ЭФФЕКТЫ В ВЫСОКОЭНЕРГЕТИЧЕСКИХ ПРОЦЕССАХ ПРИ БОЛЬШИХ Q^2

Поляризованные эффекты в инклюзивных $x \to 1$ и эксклюзивных процессах на большие углы проанализированы в рамках релятивистской кварковой модели. Рассмотрены следствия нарушения H - спин инвариантности при рассмотрении кварк-обменных и Ландсхофских диаграмм в упругом NN рассеянии.

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It is shown that in relativistic quark model, when considering quark-exchange and Landshoff diagrams in the elastic NN large-angle scattering, al spin-flip amplitudes are nonzero, which is due to the presence in relativistic wave functions of terms violating helicity conservation in the hadron-quark transition vertices $\sum \lambda_i^q \neq \lambda^h$. Polarization effects in inclusive at $x \to 1$ processes are also analyzed within the framework of the model.

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Any dynamical strong-interaction theory which claims on describing adequately physical phenomena at high energies must be able to solve a problem of spin effects correct description.

Spin correlations, together with other polarization phenomena, are fairly sensitive to hadron amplitude detailed structure, being a good criterion for theoretical predictions.

From this point of view the attempts [1-3] to apply perturbative quantum chromodynamics (QCD) in order to describe the polarization experiments in elastic large-angle NN scattering are evidently non-satisfactory. For instance, experimental data at $P_{\Lambda a \delta}$ = 12 GeV/c [4] show variation of spin correlation parameter A_{nn} (colliding beams are polarizaed normal to the scattering plane) from the quantity $A_{nn} \lesssim 0.1$ at a scattering angle in the c.m.s. $\theta_{c.m.} \leq 60^{\circ}$ up to $A_{nn} \simeq 0.6$ at $\theta_{c.m.} \lesssim 90^{\circ}$. The asymmetry parameter A in the $pN \to pN$ scattering [5] (initial beam is polarized upwards (downwards), normal to the scattering plane P =6 GeV/c) is nonzero.

The data analysis [4] carried out in Refs. [1,2] within the quark interchange model assuming that quarks interact with each other (according to QCD) by exchanging one or a few gluons (Fig.1) leads, as contrary to the experimental data, to the value of A_{nn} = 1/3 and the vanishing of quantity of A. These results are a consequence of the H -spin invariance of quark amplitudes [2] as well as a consequence of a hypothesis of helicity conservation in the hadron-quark transition vertices.

The introduction of non-perturbative mechanisms, e.g. instanton exchanges in qq scattering [1], π or σ -meson exchanges [2], allows one to enhance A_{nn} up to the experimental value; however, besides great uncertainties available in the both variants, the asymmetry A in all mechanisms is predicted to be zero (see also [6]) at any values of scattering angle.

To our mind, the description of the available data on the polarization experiments is connected not only with the adequate specification of the scattering mechanism, but also with the correct description of the bound state wave function structure. The purpose of this work is to emphasize the importance just of this aspect in the spin phenomena consideration.

We procced from the concept that hadrons can be treated as bound states of space-separated quark constituents [7,8,9]. In favour of a constituent model there exist many convincing arguments. Here should be mentioned relations between amplitudes and cross sections of exclusive reactions, some features of many-particle reactions and hadron-nuclear collisions at high energies, success in the hadrons static characteristic description [10-12]. Quarks in hadrons must be relativistic. This is most evident in the consideration of the radiative decays of meson and nucleon resonances, when the emitted photon momentum is comparable with the quark mass, and quark that had interacted with photon turns out necessarily relativistic. A crucial argument in favour of such a model is a self-consistent description of the data on the magnetic moments, electromagnetic radii and on the ratio

G_A/G_V for nucleon carried out in Ref.[9].

A relativistic quark model is based on a space-time picture of interaction in the old-fashioned (time-ordered) perturbation theory in the infinite momentum frame (IMF). The IMF is used to minimize the vacuum fluctuations, which makes it possible the relativistic description of a closed system with finite number of degrees of freedom, the interaction picture being analogous to that in the non-relativistic quantum mechanics. This enables one to define the hadron-quark transition vertex functions by analogy with the nonrelativistic bound state wave functions.

As a direct consequence of such a model, a complex correlation between the interacted hadron helicity and the helicities of its constituents arise. In a hadron wave function there appear components for which the sum of quarks helicities is not equal to hadron helicity. The origin of such components can be easily examined on the example of the construction of meson vertex function [9]. In such a model the $\pi \to q\bar{q}$ transition vertex $\Gamma^{\pi}_{S_1,S_2}$ is built up so that in the c.m.s. of constituent quarks it would be of the usual nonrelativistic form [9]:

$$\Gamma^{\pi}_{S_1,S_2} = \frac{i\,\delta_{ij}}{M_{12}\sqrt{6}}\,\bar{u}^i(P_1)\gamma_5 u^j(-P_2)\cdot\varphi^{\pi}(P_{12})\Big|_{\vec{P}_{12}=0} \tag{1}$$

$$= \frac{\delta_{ij}}{\sqrt{6}}\,\overset{+}{W}{}^i_{S_1}\, i\sigma_2 W^j_{S_2}\cdot\varphi^{\pi}(P_1,P_2)$$

$i,j(S_1,S_2)$ are colour (spin) indices of quarks; W^i_S are two-component spinors; $P_{12}=P_1+P_2$ is total 4-momentum of a two-quark system; $M_{12}=\sqrt{P_{12}^2}$ is its invariant mass (which does not coincide with π- meson mass).

Components with $\sum_i S_i \neq 0$ arise in the vertex function in IMF. One may be easily convinced in that by introducing for quarks a Feynman parametrization

$$\vec{P}_i = x_i \vec{P} + \vec{K}_{i\perp}, \quad \sum_{i=1}^{2} \vec{K}_{i\perp} = 0, \quad \sum_{i=1}^{2} x_i = 1$$

$$\mathcal{E}_i = x_i |\vec{P}| + \frac{m_i^2 + \vec{K}_{i\perp}^2}{2|\vec{P}| x_i}, \qquad M_{12}^2 = \frac{\vec{K}_{1\perp}^2 + m^2}{x_1 x_2} \tag{2}$$

and writing down (1) in explicit form at $\vec{P}_{12} = \vec{P} \to \infty$

$$\Gamma^{\pi}_{s_1,s_2}\Big|_{\vec{P}_{12}\to\infty} = \frac{i\delta_{ij}\cdot\varphi^{\pi}(P_1,P_2)}{\sqrt{6}\, M_{12}\sqrt{x_1 x_2}} \overset{+}{W}{}^{i}_{s_1}\left(m\sigma_2 - i\varepsilon_{\alpha\beta}\sigma^{\perp}_{\alpha} K^{\perp}_{\beta}\sigma_2\right) W^{j}_{s_2} \equiv$$

$$\equiv \frac{i\delta_{ij}\,\varphi^{\pi}(P_1,P_2)}{\sqrt{6}} \overset{+}{W}{}^{c_i}_{s_1}\sigma_2 W^{c_j}_{s_2} \tag{3}$$

Here $W^{c}_{s} = \sum_{s_1} W_{s_1} U_{s_1,s}(K_i)$, $U(K_i)$ is the Melosh matrix [13]

$$U(K_i) = \frac{m_i + M_{12}x_i + i\varepsilon_{\alpha\beta}\sigma^{\perp}_{\alpha}K^{\perp}_{\beta}}{\sqrt{\vec{K}_{i\perp}^2 + (m_i + M_{12}x_i)^2}}$$

Note that it seems impossible to construct a relativistic-invariant function Γ which is of a usual SU(6) structure in the IMF and has correct nonrelativistic limit.

The analogous arguments lead to the following relativistic-covariant form of the proton wave function [9] (colour indices are omitted)

$$(\psi_P)^{S}_{s_a,s_b,s_c} = \Big\{ \frac{1}{4\sqrt{2}M_0^2}\bar{U}_S(P_0)U^{u}_{s_c}(P_c,P_0)\Big[\tilde{U}^{u}_{s_a}(P_a,P_0)C\gamma_5 U^{d}_{s_b}(P_b,P_0) -$$

$$- \tilde{U}^{d}_{s_a}(P_a,P_0)C\gamma_5 U^{u}_{s_b}(P_b,P_0)\Big] + \text{transpositions}\,(a,b,c)\Big\}\cdot\varphi(P_a,P_b,P_c) \tag{4}$$

$$u_s(p_i, p_o) = \frac{\hat{p}_o + M_o}{\sqrt{2(p_i p_o + m_i M_o)}} u_s(p_i),$$

$$\vec{P}_o = \vec{P}_a + \vec{P}_b + \vec{P}_c, \quad M_o^2 = \sum_{i=a,b,c} \frac{\vec{P}_{i\perp}^2 + m_i^2}{x_i}$$

Quark distribution in hadron is described by the function $\varphi(P_a, P_b, P_c)$ so one may assume for the latter the following parameterization $\varphi(P_a, P_b, P_c) \equiv$ $\equiv \varphi(M_o^2) = N\exp(-M_o^2/\alpha^2)$ [9] corresponding in nonrelativistic limit to the oscillator potential. In the system $\vec{P}_o = 0$ we have the usual SU(6) structure, while in IMF

$$\left(\Psi_p\right)^S_{S_a,S_b,S_c \; p\to\infty} = \left\{\frac{1}{\sqrt{2}}\left(\overset{+}{W}_S W^{C_u}_{S_c}\right)\left(\tilde{W}^{C_u}_{S_a}\sigma_2 W^{C_d}_{S_b} - \tilde{W}^{C_d}_{S_a}\sigma_2 W^{C_u}_{S_b}\right) + (a,b,c)\right\}\overset{p}{\varphi}(M_o^2) \quad (5)$$

Again we have components $\sum_{i=a,b,c} S_i \neq 1/2 \left(W^C_S = \sum_{S_1} W_{S_1} U_{S_1 S}(K_i), M_{12} \to M_o\right)$

Note that the use of SU(6) wave function in the IMF would lead to an absurd result - vanishing of nucleon anomalous magnetic moment.

Thus in the IMF in vertex functions of the hadron-quark transition helicity is not conserved, $\sum S_i \neq S^h$, in other words, for hadronic amplitudes the invariance $SU_H(2) \otimes SU_I(2)$ is, generally speaking, violated.

Such invariance violation does not take place in the calculations of the leading asymptotics of a number of processes, permitting the separation of large and small distances. In this case the symmetry arguments lead to the vanishing of terms violating the helicity conservation in the hadron-quark transition vertices. For example, in the inclusive process $e^- N \to e^- + X \; (x \to 1)$ a dominating mechanism leading to such a factorization is given by the diagram of Fig.2a [14] . The squares of 4-momentum of virtual particles in this diagram are large ($\sim \frac{m^2}{1-x}$), so one may neglect the dependence of transverse momenta of initial quarks $\vec{P}_{i\perp}$, when calculating the leading asymptotics. Making use of both the symmetry of the matrix elements with respect to momenta replacement P_a, P_b, P_c and the cancellation of odd powers of $\vec{P}_{i\perp}$ in integrals over $d^3 P_i$, one can easily see that the vertex function (5) reduces effectively to the usual SU(6) wave function

$$\left(\Psi_P\right)_{S_a,S_b,S_c} \longrightarrow \Psi_{S_a,S_b,S_c}(SU(6)) \frac{\left[(M_0 X_a+m)(M_0 X_b+m)+P_a^\perp P_b^\perp\right]\cdot(M_0 X_c+m)}{\prod_{i=a,b,c}\sqrt{\vec{P}_{i\perp}^2+(m_i+M_0 X_i)^2}} \tag{6}$$

A structure function of nucleon $F_\perp(x)$ behaves as $(1-X)^3$ and the helicity of the initial particle coincides with that of the interacted quark Any other configuration of helicities is suppressed as $(1-X)$ in the amplitude, and to estimate the latter it is necessary to take into account the terms with $\sum_i S_i \neq 1/2$ in wave function.

For mesons one of the vertices in Fig.2b may depend on the initial transverse momentum $K_\perp$, and terms not conserving total helicity in (3) may give, generally speaking, nonzero contribution. The behaviour over $(1-X)$ remains, however, the same: $F_\perp(x)\sim(1-x)^2$, $F_L(x)\sim\frac{m^2}{Q^2}\cdot(1-x)^{2|\lambda|}$ $\frac{m^2}{Q^2} \ll 1-X \lesssim \sqrt{\frac{m^2}{Q^2}}$, λ - is the initial particle helicity. Note that the account of higher orbital angular momentum in the wave function [9] also does not affect the results of [14]. The analogous result (formula 6) also takes place when considering the asymptotic behaviour of formfactors in QCD.

A more complicated situation arises when considering spin effects in elastic NN-scattering. The analogous considerations can be applied also to the diagrams of Fig.1d type which gives the differential cross section behaviour being in agreement with the quark counting rules $\frac{d\sigma}{dt} \sim \frac{1}{S^{10}}$ [16,17].

Quark amplitudes in the main in $\frac{1}{Q^2}$ approximation in this case are independent of quark transverse momenta and are symmetric relative to replacements of longitudinal momenta (by a sum of diagrams of Fig.1d type). The number of the integrations coincide with that of independent momenta of quark internal motion in $N \to qqq$ transition vertices. As a result, in each of the vertices the vertex functions (5) reduce effectively to the standard SU(6) wave function in accord with formula (6), and all the results of Refs.[1,2] concerning the spin dependence remain valid.

However, one should keep in mind that in the existing experiments the asymptotic values of momentum transfer corresponding to the considered mechanism is apparently not achieved. Besides non-satisfactory description of spin correlations, this mechanism does not apparently give a correct absolute value of NN-scattering differential cross section, which is due to a poor description of formfactors in perturbative QCD (see, e.g. [19-21]). Indeed, differential cross section written for estimates in the form of $d\sigma/dt(NN \to NN) = C F_N^2(t) F_N^2(u)/S^2$ contains a fourth power of formfactor, and the factor C which takes into account the number of diagrams is not large enough to compensate the asymptotic smallness of $F_N^4(t)$.

In the kinematic region of the existing experiments an essential role may play the Landshoff diagrams [18], which in asymptotics, generally speaking, are suppressed by Sudakov's formfactors (see, e.g. [2]), as well as non-asymptotic quark-exchange diagrams of Fig.1a,b,c type in which the number of gluons is less than five. Such diagrams are suppressed asymptotically by the smallness of wave functions near the spectrum boundary. However as one can see from the analysis of the pion formfactor in the relativistic quark model [21], at moderate q^2 such a suppression is not large and pion formfactor can be described by a simplest quark diagram without gluon-exchange. One should therefore expect that diagrams of Fig.1a,b,c type in the preasymptotic region must contribute significantly. When treating dimilar mechanisms of NN scattering, the terms with $\sum_i S_i \neq S^h$ in the wave functions of fast hadrons violating the $SU_H(2) \otimes SU_I(2)$ invariance turned out significant.

Consider in more detail the Landshoff scattering mechanism (diagrams of Fig.3a,b type). The "annihilation" type diagrams in Fig.3b are suppressed by an additional power of $\frac{1}{q^2}$ [16]. In the analysis it is convenient to use IMF which is derived from the c.m.s. of initial particles by Lorentz boost in the direction normal to the scattering plane

$$P_A = (\gamma E^*, 0 | P^* |, \gamma V E^*),\ P_C = (\gamma E^*, |P^*| \sin\theta^*, |P^*| \cos\theta^*, \gamma V E^*) \quad (7)$$
$$P_B = (\gamma E^*, 0, -|P^*|, \gamma V E^*),\ P_D = (\gamma E^*, -|P^*| \sin\theta^*, -|P^*| \cos\theta^*, \gamma V E^*)$$

where θ^* is scattering angle, P^* is momentum in c.m.s.

In the diagrams of Fig.3 type the number of independent integrations is less than that of independent quark momenta between which the following re lations take place:

$$\vec{K}_{iA} + \vec{K}_{iB} - \vec{K}_{iC} - \vec{K}_{iD} - (X_{iD} - X_{iA})\vec{q}_\perp - (X_{iC} - X_{iA})\vec{\tau}_\perp = 0 \quad (8)$$
$$i = 1, 2$$

When deriving Eq.(8) the Feynman parametrization was used for constituent quark momenta $\vec{P}_{im} = X_{im}\vec{P}_m + \vec{K}^\perp_{im}$ $(i = 1,2,3;\ m = A,B,C,D)$

$$\vec{K}^\perp_{im} \cdot \vec{P}_m = 0,\ \sum_i X_{im} = 1,\ 0 \leq X_{im} \leq 1,\ \sum_i \vec{K}^\perp_{im} = 0$$

In the reference frame (7)

$$q = (0, -|P^*| \sin\theta^*, |P^*|(1 - \cos\theta^*), 0),\ \tau = (0, |P^*| \sin\theta^*, |P^*|(1 + \cos\theta^*), 0),$$
$$q^2 = t\ , \quad \tau^2 = u$$

As it follows from relation (8), the invariant mass of the system of quarks composing a hadron turns out dependent on momenta of quarks not entering that hadron; hence in integrating there arises overlapping of hadron wave functions, so the odd powers of $\vec{K}_{im}^{\perp}$ in the Melosh matrices do not vanish.

The leading asymptotics of the Landshoff diagrams $\sim 1/S^3$ is defined by the "pinch"-singularity region.

$$|X_{1D}-X_{1A}|\lesssim\frac{\alpha}{q_\perp},\ |X_{2D}-X_{2A}|\lesssim\frac{\alpha}{q_\perp},\ |X_{1C}-X_{1A}|\lesssim\frac{\alpha}{\tau_\perp},\ |X_{2C}-X_{2A}|\lesssim\frac{\alpha}{\tau_\perp} \qquad (9)$$

where $\alpha^2\sim\langle K_\perp^2\rangle$ (see, e.g. [22]). From the explicit form of the Melosh matrices one can see that in this region terms $\sim i\varepsilon_{mn}\sigma_m q_n(X_{iD}-X_{iA})$ determining the spin flip turn out of the same order as non-flip terms.

Thus, if there are no casual cancellations, the total hadronic amplitude is already not $SU_H(2)\otimes SU_I(2)$ invariant, the total hadron helicity is not conserved, $\Delta\lambda=\lambda_f-\lambda_i\neq 0$, and all independent helicity amplitudes describing NN scattering are nonzero. Recall that these results are obtained in the IMF (7). The helicity amplitudes in c.m.s. $M(++,++)=\Phi_1$,

$$M(+-,+-)=\Phi_3,\ M(-+,+-)=\Phi_4,\ M(++,+-)=\Phi_5\ M(--,++)=\Phi_2$$

are connected with those in IMF in a complicated manner, however one can easily be convinced that all amplitudes Φ_i are also nonzero and turn out of the same order. The relation $A_{nn}=-A_{\ell\ell}=-A_{ss}$ does not hold ($A_{\ell\ell}$ - is asymmetry in the case of the initial spins polarized parallel (antiparallel) to the beam (z) direction, A_{ss} is asymmetry parallel to (y) direction, $A_{ii}=(d\sigma(\uparrow\uparrow)-d\sigma(\uparrow\downarrow))/(d\sigma(\uparrow\uparrow)+d\sigma(\uparrow\downarrow))$, $i=\ell,n,s$, and prediction $A_{nn}=-A_{\ell\ell}=-A_{ss}=1/3$ for PP scattering ($\theta_{c.m}=90^0$) [2] turns out wrong. Difference from zero of $\Phi_5^{n,p}$ at $\theta_{c.m}\neq 90^0$ ($\Phi_5^p=0$ at $\theta_{c.m}=90^0$ for symmetry reasons) results in that the conclusion [1]

$$A_{se}=\frac{1}{6}\,\mathrm{Re}\left(\Phi_1+\Phi_2+\Phi_4-\Phi_3\right)\Phi_5^*=0$$

for any scattering angles may be wrong, too. As for the asymmetry

$$A = -\frac{1}{6} \, Jm(\phi_1 + \phi_2 + \phi_3 - \phi_4)\phi_5^* , \quad \sigma = \frac{1}{2}\left(\sum_{i=1}^{4} |\phi_i|^2 + 4|\phi_5|^2\right)$$

the vanishing of the latter was caused in [1] not only due to the vanishing of ϕ_5 , but also due to the fact that all amplitudes under consideration are real. However outside the "pinch" region (9) an imaginary part also appears in amplitudes which though being suppressed asymptotically as $1/\sqrt{S}$, in the preasymptotic region lead to nonzero asymmetry A .

In the case of quark-exchange mechanism the "annihilation" diagrams of Fig.1e type in IMF (7) are suppressed as $1/p^2$. In diagrams of Fig.1a,b,c type just like in the case of Landshoff mechanism the separation of large and small distances does not take place; wave functions in integrals overlap and spin-flip amplitudes ϕ_2 and ϕ_5 are nonzero as well.

Note also that in the case of reggeized meson exchanges (σ , π) in the diagrams of Fig.3 type as suggested in [2] together with $\phi_2 \neq 0$ the relativization of hadron wave function also brings to nonzero amplitude ϕ_5 .

From the viewpoint of the model under discussion one can understand the negative results obtained in Ref.[3] , where the diagrams of Figs.1a and 4 were treated as main scattering mechanisms, whereas the bound-state wave functions were taken in a standard SU(6) form.

In conclusion we emphasize once more that the use of SU(6) wave functions of hadrons in IMF is not correct and contradicts the relativistic invariance. A correct form of a wave function of fast hadrons contains necessarily the term with $\sum_i S_i^q \neq S^h$. For any scattering mechanism, in which the separation of large and small distances does not take place and the wave functions overlap at integration, such terms make nonzero contribution and should be taken into account when describing spin effects.

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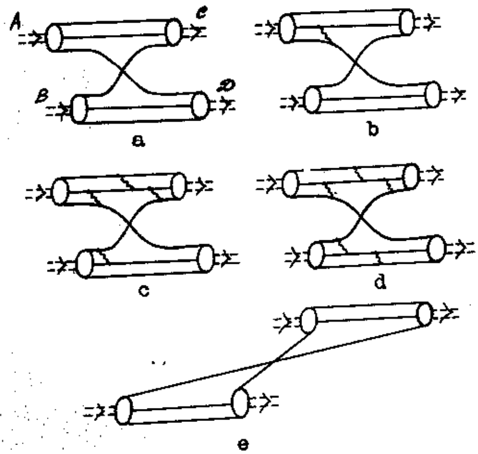

Fig.1 Quark-exchange diagrams of NN scattering.

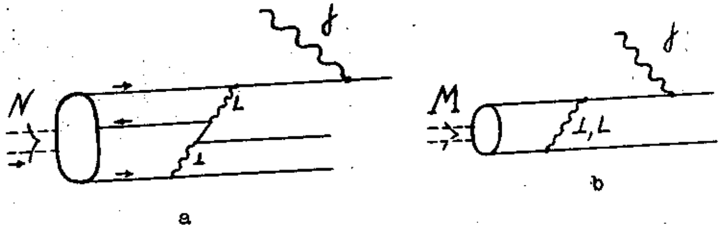

Fig.2 QCD diagrams defining the behaviour of structure functions at $x \to 1$.

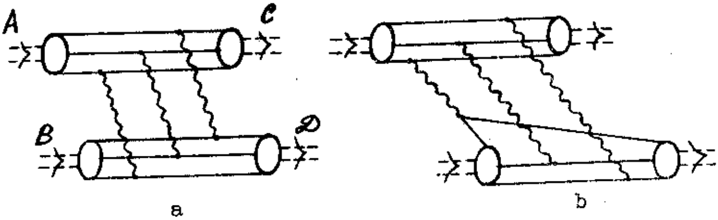

Fig.3 Three-gluon exchange diagrams corresponding to Landshoff mechanism of NN scattering.

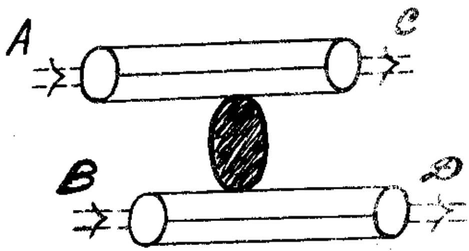

Fig.4 Quark-quark interaction diagrams without quark exchanges in NN scattering.

REFERENCES

1. Farrar G.R., Gotlieb S., Sivers D., Thomas G.H. Constituent Description of NN Elastic Scattering Observables at Large Angles.-Phys.Rev.D, 1979, vol.20, p.202-210.
2. Brodsky S.J., Carlson C.E., Lipkin N. Spin Effects in Large-Momentum Exclusive Scattering Processes.-Phys.Rev.D, 1979, vol.20, p.2278-2289.
3. Aviler C., Cocho G., Moreno M. Polarized Nucleon-Nucleon Scattering from 3 to 12 GeV/c. What Cab Be Inferred from the Experiments?-Phys.Rev.D, 1981, vol.24, p.634-646.
4. Yokasawa A. Reviews of Experimental Results from the Polarized-Beam Program at the Argonne ZGS.- Phys.Rep., 1980, vol.C64, p.47-86.
5. Makdisi Y., Marshak M.L., Mossberg B. et al. Analyzing Power in Large-Angle Proton-Neutron Elastic Scattering.-Phys.Rev.Lett., 1980,vol.45, p.1529-1533.
6. Головизин В.В.,Снигирев А.М.,Соловьев Л.Д., Щелкачев А.В. Модель упругого рассеяния адронов с большими переданными импульсами. ЯФ,1981, т.34,с.216-226
7. Терентьев М.В. О структуре волновых функций мезонов как связанных состояний релятивистских кварков. ЯФ, 1976,т.24,с.207-213
8. Берестецкий В.Б., Терентьев М.В. Динамика светового фронта и нуклоны из релятивистских кварков. ЯФ,1976,т.24,с.1044-1057.
9. Aznauryan I.G., Bagdasaryan A.S., Ter-Isaakyan N.L. Relativistic Quark Model in Infinite Momentum Frame and Static Properties of Hadrons.- EPI-550(37)-82, p.1-37.
10. Lipkin N. Quarks for Pedestrians.-Phys.Rep., 1973, vol.3C, p.173-268.
11. Шехтер В.М. За что мы любим кварки? Материалы IУ Школы физики ИТЭФ, 1976,вып.,с.38-78.
12. Анисович В.В., Шабельский Ю.М., Шехтер В.М. Рождение быстрых

частиц на ядрах в кварковой модели, ЯФ,1978,т.28,с.1063-1078
13. Melosh H.J. Quarks: Currents and Constituents.-Phys.Rev. 1974, vol.D16, p.1095-1112.
14. Григорян С.Г., Есайбегян С.В., Тер-Исаакян Н.Л. О поведении структурных функций адронов при $x \to 1$. ЯФ, 1978,т.27,с.1312-1322
15. Farrar G., Jackson D. Pion and Nucleon Structure Functions Near X=1. - Phys.Rev.Lett. 1975, vol.35, p.1416-1419.
16. Brodsky S.J., Farrar G.R. Scaling Laws for Large-Momentum-Transfer Processes.-Phys.Rev.D, 1975, vol.11, p.1309-1330.
17. Matveev V., Muradyan R., Tavkhelidze A. Automodelism in the Large-Angle Elastic Scattering and Structure of Hadrons.-Nuovo Cim.Lett. 1973, vol.7. p.719-723.
18. Landshoff P.V. Model for Elastic Scattering at Wide Angle.-Phys.Rev.D, 1974, vol.10, No.3, p.1024-1030.
19. Черняк В.Л. Асимптотическое поведение эксклюзивных амплитуд в квантовой хромодинамике. Материалы ХУ Зимней школы ЛИЯФ, Ленинград. 1980, с.65-154.
20. Aznauryan I.G., Esaybegyan S.V., Ter-Isaakyan N.L. On the Asymptotics of the Nucleon Form Factors in the Quark-Gluon Model.-Phys.Lett. 1980, vol.90B, p.151-154.
21. Bagdasaryan A.S., Esaybegyan S.V., Ter-Isahakyan N.L. Relativistic Quark Model and Behavior of the Meson Electromagnetic Form Factors at Small and Intermediate Momentum Transfer Q^2. Preprint EPI-581(68)-82.
22. Lepage G.P., Brodsky S.J., Huang T., Mackenzie P.B. Hadronic Wave Functions in QCD.- CLNS-82/522 (1982), p.1-52.

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АДРОНЫ ИЗ РЕЛЯТИВИСТСКИХ КВАРКОВ И СПИНОВЫЕ ЭФФЕКТЫ В ВЫСОКОЭНЕРГЕТИЧЕСКИХ ПРОЦЕССАХ ПРИ БОЛЬШИХ Q^2

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