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V.A.Belyakov, V.N.Strel'tsov

POSSIBLE EXPLANATION OF THE INTERACTION CROSS-SECTION GROWTH AT HIGH ENERGIES

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1. In due course the Yukawa idea[1] has played an important role for the explanation of the strong interaction behaviour, in particular, its short-range action. According to this idea nucleons interact with one another with the help of π-meson exchange. In the time the Yukawa potential (stationary meson field) takes the form

$$\phi_\pi = - g_\pi \frac{\exp(-\mu R^*)}{R^*}. \qquad (1)$$

Here g_π denotes the interaction constant, μ is the pion mass and $\hbar = c = 1$. Further on, the exchange by heavier mesons (for example, the vector ρ- and ω-mesons) has been taken into account to explain the strong interaction behaviour at small ranges. In this case along with (1) we will have the expression for the vector potential, where the corresponding meson mass figures in the exponent.

According to modern ideas, a strong interaction is described by quantum chromodynamics. At the same time this theory surely includes in itself the previous result explaining, for example, short-range nuclear forces. As far as free gluons and quarks are not observed in the nature the quark-gluon field hadronization should be introduced on the nuclear force action bound. As is seen in any case this role is quantitatively taken just by Yukawa's exponent. Thus, the usage of the relativized Yukawa potential[2] is the very justification to find out the features of the moving nucleon nuclear field behaviour. These features include their longitudinal and transverse sizes.

2. On the basis of our previously made calculations[3-5] it has been determined that the pionic field of the relativistic nucleon has the shape of a rotating ellipsoid. This ellipsoid is stretched in the direction of motion. With increasing of energy the field stretches more forward* and acts on more and more range. The degree of "stretching" (the longitudinal field

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*This stretching reminds the angular distribution behaviour of real pions in multiparticle production processes. The isotropic distribution in the center-of-mass system will be directed forward in the labsystem.

size $R_{\parallel}$) is determined by the Lorentz-factor γ. This result is in full accordance with the transformation of the surface of a sphere in the transition to the moving system within frames of the concept of relativistic ("radar") of length[6]. At the same time the action radius of the vector field grows faster and its contribution becomes dominating at $\gamma \geq 10^2$. But the more substantial is the fact that the transverse size growth for the nucleon is due to the vector field. One can say that the nucleon "swells". It is seen that the growth of the interaction cross-section at high energies observed earlier[7,8] has just the same nature, i.e. is due to the action of the nuclear field quanta with spin. It should be noted that here we have the definite analogy with the logarithmic growth of ionizating losses at relativistic velocities (due to far collisions).

Although our previous approach could be called out-of-date and seems difficult to adapt to pionic processes, we think this point of view surely reflects the physical nature of the discussed phenomenon.

Other known phenomena[4] also are explained in the frames of our approach. The growth of the length formation due to increasing of the longitudinal nucleon size is the most distinctive example here.

3. The idea of the quark structure for the hadron content allows one to reach more uniform "modern" description of the nucleon size behaviour at high energies. As is known, the interaction between quarks inside the nucleon is carried out by the gluon exchange. Just the quarks form the "bound range" of nucleons do join the gluon threads. The string model can be seen here as an obvious case.

Therefore we have to examine the quark (i.e. spinor) field behaviour in the frames of our approach. In this case the Lorentz transformation to the moving system gives the factor $\sqrt{(\gamma+1)/2}$ in the spinor wave function (unlike the vector field this factor is equal to γ). So, the relativistic Yukawa potential for the quark field will have the form

$$\phi_q = -g_q \frac{\sqrt{u^0+1}\,\exp(-\mu_q u^i R_i)}{\sqrt{2}\,u^i R_i}\,. \qquad (2)$$

Here μ_q denotes the quark mass μ_q=336 MeV, u^i is the hadron 4-velocity ($u^0 \equiv \gamma$), R_i is the 4-vector of a retarded distance*. i = 0, 1, 2, 3.

*At the same time it is tacitly supposed the quark velocity is equal to the light one. In this connection see, e.g. [9].

Table

γ	π	q		ρ,ω
	$R_{\parallel}/2\gamma$, $R_{\perp}$ [μ^{-1}]	$R_{\parallel}/2\gamma$, $R_{\perp}$	$a(\ln\gamma)^{0.8}$	$R_{\parallel}/2\gamma$, $R_{\perp}$
1	1	0.41		0.36
10	1	0.68		0.66
10^2	1	1.0	1.0	1.0
10^3	1	1.4	1.4	1.4
10^4	1	1.7	1.7	1.7
10^5	1	2.1	2.1	2.1
10^6	1	2.5	2.4	2.5

The results of calculation on the basis of formula (2) are given in the middle of the Table. The large ellipsoid axis $R_{\parallel}$ denotes the longitudinal field size, the small semi-axis $R_{\perp}$ denotes the radius of the transverse field section. The value g_q (=0.6 g_π) is fitted to equalize $R_{\perp}^q = R_{\perp}^\pi$ at $\gamma=10^2$ that corresponds to the experimental growth of the interaction cross-section. The previous data for pionic and vector field are presented in the table for comparison.

As is seen, the growth of the transverse hadron size due to the quark field is described by the function $(\ln\gamma)^{0.8}$ sufficiently well.

It should give the corresponding growth of the cross-section in proportion to $(\ln\gamma)^{1.6}$*.

At present this result may be considered to be the only physical ground for the discussed experimental fact. As it is seen so, on the other hand, one could consider this result as the inderect evidence in favour of the quark structure of hadrons.

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*The large growth of the cross-section will indicate the gluon field influence.

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Беляков В.А., Стрельцов В.Н. E2-92-368

Возможное объяснение роста сечений взаимодействия при высоких энергиях

На основе релятивизованного потенциала Юкавы для кваркового поля показано, что поперечные размеры движущихся адронов растут с увеличением энергии $\sim (\ln\gamma)^{0.8}$, где γ - лоренц-фактор. Высказывается мнение, что известный рост сечений взаимодействия при высоких энергиях обусловлен именно указанной причиной.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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Possible Explanation of the Interaction Cross-Section Growth at High Energies

On the basis of the relativized Yukawa potential it is shown that the moving hadron "transverse size" grows with increasing its energy $\sim (\ln\gamma)^{0.8}$ (γ is the Lorentz-factor). The opinion is expressed that the known growth of the interaction cross-section at high energies is due to the indicated reason.

The investigation has been performed at the Laboratory of High Energies, JINR.

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