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DYNAMICS OF COLOUR IN HADRON DIFFRACTION ON NUCLEI

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1. It is known that corrections to the Glauber-Sitenko model, due to inelastic shadowing[1] "enlight" the nuclei, i.e., suppress the elastic scattering cross section and increase the diffractive dissociation one[2]. Even the first inelastic correction[3] allows one to describe satisfactorily the hadron-nucleus total cross section data[4,5]. It is impossible, however, to calculate more complicated inelastic corrections without any additional assumptions. In the case of the diffractive dissociation, it is impossible to calculate even the simplest inelastic correction. The estimations made in ref.[2] show however that such correction is very large.

The eigenstate method for calculation of hadron-nucleus diffraction amplitude[2,6,7] sums up effectively all the inelastic corrections. But all the eigenstates of the interaction should be known in this approach. This can be found in some theoretical model only. One example[6,7] is the parton model, where the hadron components with a definite wee-parton number play a role of eigenstates.

2. In the quantum chromodynamics the Born approximation (double gluon exchange) gives a good description of hadron-nucleon diffraction scattering data and reproduces yet some delicate features of these processes[8-10].

In such approximation, adopted below, the two-quark-system forward scattering amplitude on a nucleon, when the transverse interquark distance has definite value ρ, has the form

$$f(\rho) = i\,\frac{8}{3}\,\alpha_s^2 \int \frac{d^2k}{k^4}\,(1 - e^{-i\vec{k}\vec{\rho}})(1 - S_N(k)). \qquad (1)$$

Here α_s is the QCD constant, which value is discussed in ref.[8-10]. $S_N(k) = \langle \exp[i\vec{k}(\vec{r}_1 - \vec{r}_2)] \rangle_N$ is a nucleon double quark form factor, where the averaging is performed over nucleon quark coordinates r_i. If the energy is large enough the quark motion inside the incident hadron is relativistically slowed down. So expression (1) shows that the eigenstates of the scattering amplitude operator are the states with a definite value of ρ, whose eigenvalues are given by (1).

3. In the eigenstate method the hadron-nucleus partial wave amplitude has the form [6]

$$-iF(b) = 1 - \langle \exp[if(\rho)T(b)] \rangle_h . \qquad (2)$$

Here b is an impact parameter of the incident hadron (meson) h ; the averaging is taken over the interquark distance ρ; T(b) is the nuclear profile function. For the sake of clarity the optical approximation is used in (2).

The partial wave cross section of the diffractive dissociation into all the final states except the elastic one is equal to

$$\sigma_{diff}(b) = \langle \exp[2if(\rho)T(b)] \rangle_h - \langle \exp[if(\rho)T(b)] \rangle_h^2 . \qquad (3)$$

The calculations are made with two form factor parametrizations: i) the pole form $S_a(k) = \mu_a^2/(k^2+\mu_a^2)$, where a=h,N; ii) the Gaussian form $S_a(k) = \exp(-k^2/\lambda_a^2)$. The parameters μ_a, λ_a are connected with hadron and nucleon radii. In the last case the amplitude (1) has the form

$$f(\rho) = \frac{1}{2}\sigma_{tot}^{hN}\,[\gamma \ln(1+1/\gamma) + \ln(1+\gamma)]^{-1} \times$$
$$\times [1-\exp(-z^2/4) + C + \ln(z^2/4) + (1+z^2/4)Ei(-z^2/4)] . \qquad (4)$$

Here $z=\lambda_N\rho$; $\gamma=\lambda_h/\lambda_N$; $C = 0.577$ is the Euler constant.

4. The calculation of σ_{tot}^{hA} in accordance with formulas (2), (4) shows that the total inelastic shadowing correction for the real nuclei does not differ significantly from the first simplest correction [3].

In the case of diffractive dissociation we made the following theoretical "experiment" [7]. The pion-nucleus diffractive dissociation cross section calculated by formulae (3),(4) has been compared with expression [11], which does not contain any inelastic shadowing contribution (corresponding to the usual procedure for the experimental data analysis). The unknown parameter σ_{tot}^{XN} - average absorption cross section of the produced particle system, which is extracted by this procedure is equal for the nuclei $^{12}C \to {}^{208}Pb$ to $\sigma_{tot}^{XN}/\sigma_{tot}^{\pi N} \approx 0.75$. Note that in the case of Gaussian parametrization of $S_a(k)$ the value of σ_{tot}^{XN} is found to be negative at all. Thus one can see that the frequently discussed abnormal smallness of σ_{tot}^{XN} is a consequence of the inelastic shadowing neglect to the data analysis (compare with ref. [2]).

5. Earlier we have described the diffraction processes in the framework of quark-parton model [6,2]. In this case the enlighting of a nucleus is caused mainly by the passive component of the constituent quark. In the model discussed here there is no straight analogy to the passive component because the time needed for a double gluon exchange is about $1/m$. Nevertheless, as hadron is a colourless object, its interaction with the gluon field of a target is of dipole kind*. For this reason, if $\rho \to 0$ then $f(\rho) \sim \rho^2$ (see expr. (1)), i.e., the hadron in such configuration is passive. As can be seen from expression (2) the transparency of a very thick nucleus ($T(b) \to \infty$) tends to zero as $1/T(b)$ unlike to the parton model prediction. Nevertheless this decrease is very slow.

6. The analysis [12] of Φ-meson photoproduction off nuclei data gives a paradoxical result: $\sigma_{tot}^{\Phi N}$ is considerably smaller than the value predicted by the additive quark model. One can see now that as Φ-meson consists of two heavy s-quarks its radius is much smaller than the radii of π and K mesons. This fact and expression (1) lead to smallness of $\sigma_{tot}^{\Phi N}$ (see ref. [8]).

7. Expression (2) is valid if $E/m^2 \gg R_A$, i.e., when the mixing of the hadron components with different values of ρ can be neglected. At intermediate energies, however, one must involve the component mixing, which is equivalent to taking into account the longitudinal impulse transfer and nuclear form factor [13]. But this requires the knowledge of hadron quark-wave function.

8. The present approach ignores the contamination of transverse gluons to the relativistic hadron wave function. For this reason the model cannot reproduce correctly the mass distribution of the diffractive dissociation cross section. It is clear that the triple pomeron contribution is absent here at all, and quark exchange is not reggeized. So this model needs some further development.

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*This pattern is very like the propagation of positronium through matter.

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