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MECHANISM OF INCLUSIVE REACTIONS AND INELASTIC SCREENING IN THE DEUTERON

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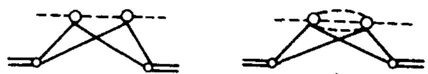
The purpose of this paper is to estimate the contribution of different elastic mechanisms to the shadow correction $\Delta = \sigma_p + \sigma_n - \sigma_d$ in the scattering of a hadron of high energy, $E_{lab} > 10$ GeV, by a neutron. The shadow correction contains contributions of the elastic screening $\Delta_{el} = (4\pi)^{-1} \langle R^{-2} \rangle \sigma_p \sigma_n$ [1] (Fig. a) and of inelastic screening Δ_{inel} [2 - 4] (see Fig. b): $\Delta = \Delta_{el} + \Delta_{inel}$. In the calculation of Δ_{inel} we shall use the experimental data on inclusive reactions a + N → X + N and the Regge phenomenology [5][1].



a b

If an inclusive process a + N → X + N is described by interfering contributions of several reggeons (the reasoning is given below), then the inelastic shadow correction Δ_{inel} is represented in the form

$$\Delta_{inel} = 2 \int dt\, ds' F(t) \sum_i \xi_i \frac{d^2\sigma^i(s_1, s', t)}{dt\, ds'}, \qquad (1)$$

where $d^2\sigma^i(s_1, s', t)/dtds'$ is the differential cross section for the production of a beam of particles with mass $M = \sqrt{s'}$ as a result of exchange of the i-th reggeon, $s_1 = (p_a + p_N)^2$, $F(t) = \exp(at)$ is the form factor of the deuteron, and $a = 40$ GeV^{-2}. The factor ξ_i is determined by the phase of the amplitude for the production of a given beam of particles and is equal to $\xi_i = -\sigma_i \cos\pi\alpha_i(t)$, where $\sigma_i = \pm 1$ and $a_i(t)$ is the signature and the trajectory of the i-th Regge pole.

In the estimates of Δ_{inel} in [2, 4] it was assumed that the amplitude of the inclusive reaction a + N → X + N is determined entirely by the contribution of the vacuum pole P, and that $\xi_i = 1$. This assumption, however, contradicts the available experimental data on inelastic spectra. As shown in [7], the contribution of the P-pole (or of diffraction dissociation) to the cross section of the process p + p → p + X is a small fraction (about 10%) of the total inelastic cross section σ_{inel} and is concentrated mainly in the region of small masses, $M \leq 2$ GeV. At the same time, at very high energies, $s_1 \gg m^3\sqrt{a}$, an appreciable contribution to Δ_{inel} can be made in accord with (1), by inter-

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[1] An interesting qualitative analysis of different inelastic contributions to Δ_{inel} for Nd scattering was performed within the framework of the Regge scheme and the hypothesis of duality in the mean in [6].

mediate states with large masses $M^2 \sim s_1/m\sqrt{a}$. According to [8], the cross section for the production of beams with such masses decreases with energy approximately like $1/s_1$, and is therefore connected with exchange of secondary Regge poles P', ω, π, etc. Since the contributions of the vacuum and secondary poles are concentrated in different regions of M, the interference between them can be neglected, and Δ_{inel} can be represented in the form of a sum of these two contributions:

$$\Delta_{inel} = \Delta_P + \Delta_B. \tag{2}$$

Regardless of the mechanism that produces beams of large-mass particles, it is possible, by using the experimental information on the cross section of the process a + N → X + N and recognizing that $|\xi_i| \leq 1$, to obtain an upper bound for Δ_B:

$$\Delta_B \leqslant \pi \int dp_\perp^2 \frac{dx}{x} [\rho_B(s_1, x, p_\perp) + \rho_B^{ch.ex}(s_1, x, p_\perp)] e^{-\frac{a}{x}(p_\perp^2 + m^2(1-x)^2)}, \tag{3}$$

where the invariant functions ρ_B and $\rho_B^{ch.ex}$ are connected with the cross sections of the inclusive processes a + p → X + p and a + p → X + n by the relation

$$\rho(s_1, t, M) = \frac{s_1}{\pi \sigma_{inel}} \frac{d^2\sigma}{dt\, M dM},$$

$p_\perp$ is the transverse component of the momentum transferred to the nucleon, and $1 - x = (M^2 - m_a^2)/s_1$.

The main contribution is made to the integral (3) by the region of small $1 - x \sim 1/m\sqrt{a}$, in which the function ρ is practically independent of x [8]. Therefore, after integrating with respect to $p_\perp$ and x in (3) we obtain

$$\Delta_B \leqslant \Delta_B^{max}, \quad \Delta_B^{max} \leqslant \frac{\pi\sqrt{\pi}}{ma^{3/2}} \bar{\rho}\, \sigma_{inel}, \tag{4}$$

where

$$\bar{\rho} = \frac{1}{2} (\rho_B + \rho_B^{ch.ex}) |_{p_\perp = 0,\ x = 1 - \gamma/m\sqrt{a}},\ \gamma \sim 1.$$

According to [8], for the process p + p → p + X, we have ρ_B ($p_\perp = 0$, x = 0.9) = 2 GeV^{-2} and is practically independent of the energy. If we assume that $\rho_B^{ch.ex} = \rho_B$, then $\Delta_B < 1.8$ mb. Thus, the upper limit of Δ_B is quite large. (We recall that $\Delta_{el} \simeq 3$ mb for pd scattering.) Such a limit would be reached under the condition $\xi_i \sim 1$. On the other hand, if it is recognized that the main contribution is the mass region $M^2/s_1 \sim 1/m\sqrt{a}$ is made by the P' and ω poles with $\alpha_i(0) = 1/2$ (corresponding to a linear decrease of $d^2\sigma_B/dtdM^2$ with increasing M^2 and to independence of the function ρ_B of x), then $\xi_i \simeq \varepsilon$, where $\varepsilon = \alpha_{P',\omega}(0) - 1/2 \lesssim 0.1$ [9], and consequently $\Delta_B \sim \Delta_B^{(P',\omega)} \lesssim \varepsilon\Delta_B^{max}$. The smallness of the contribution of the poles with $\alpha(0) = 1/2$ to the shadow correction was noted earlier in [6]. More remote poles, say π, also make a small contribution to Δ_B, for in this case the invariant function $\rho_B \sim (1 - x)^{1-2\alpha_i(t)}$ is close to zero in the region of small 1 - x, and therefore $\Delta_B^{(\pi)} < (1/m\sqrt{a})\Delta_B^{max}$. We note that there is no interference between the contributions of the poles P', ω, and π between P' and ω or π by virtue of the G-parity selection rules and between ω and π owing to the different spin structures of the $\omega N\bar{N}$ and $\pi N\bar{N}$ vertices).

The foregoing considerations allow us to conclude that the large-mass region makes a small contribution to the shadow correction, $\Delta_B < 0.1\,\Delta_{el}$. For heavier nuclei, the contribution of the large masses is even less significant, since Δ_B is inversely proportional to the volume of the nucleus.

The contribution of the diffraction dissociation Δ_P in the energy region $s_1 \gg m^3\sqrt{a}$ is conveniently presented in the form

$$\Delta_P = 2\sigma_P \bar{b}_P(a + \bar{b}_P)^{-1}, \tag{5}$$

where σ_P is the cross section for the production of a particle beam by diffraction dissociation and b_P is the average slope of the diffraction cone for these processes. Since the elastic shadow correction Δ_{el} can also be represented in analogous form [4]

$$\Delta_{el} = 2\sigma_{el} b_{el}(a + b_{el})^{-1}, \tag{6}$$

where σ_{el} and b_{el} are the cross section and slope of the diffraction cone for elastic scattering, we get, recognizing that $\bar{b}_P \simeq b_{el}$ [7],

$$\Delta_P / \Delta_{el} = \sigma_P / \sigma_{el}. \tag{7}$$

Using the values of σ_P obtained in [7], we get $\Delta_P/\Delta_{el} = 0.20 \pm 0.04$, 0.38 ± 0.13, and 0.50 ± 0.20 for pd, πd, and Kd scattering, respectively. For heavier nuclei, the contribution of the diffraction dissociation will reach values of the same scale at higher energies $s_1 = 2mE \gg m^3R$.

At an energy E > 10 GeV, when the parameter $m^3\sqrt{a}/s_1$ is still not very small, Δ_P increases very little with energy. This increase can be described by the formula

$$\Delta_P = C_1 - C_2[\ln(s_1/m^3\sqrt{a})]^{-1}, \tag{8}$$

which is obtained under the assumption that the mass spectrum for the diffraction dissociation decreases in the minimum possible fashion with increasing M, $d^2\sigma_P/dt\,dM^2 \sim 1/M^2 \ln^2 M^2$.

The absolute values of the shadow correction, calculated from the formula $\Delta = \Delta_{el} + \Delta_P$, where Δ_P and Δ_{el} are given by formulas (5) - (6), and the energy dependence of this correction [8] is in satisfactory agreement with the experimental data for πd scattering in the energy region 15 - 60 GeV [10].

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POSSIBLE EXISTENCE OF I^+ RESONANCE IN CHARGE EXCHANGE REACTIONS OF SPHERICAL NUCLEI

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Charge-exchange reactions of the type (p, n), (He^3, t), or inverse β decay (ν, e^-) make it possible to investigate the isobaric configuration proton - neutron hole states (p, $\bar{n}$) of a target nucleus A(N, Z) (N > Z) [1], such as the collective configuration 0^+ states of even-even nuclei [2, 3]. Among the configuration isobaric states of other angular momenta, it is of interest to investigate the experimental possibility of existence of a collective isobaric I^+ state, which can be manifest in charge-exchange reactions of even-even nuclei A(N, Z) as "giant" I^+ resonance against the background of compound states of the odd-odd nucleus A(N - 1, Z + 1). From the microscopic point of view, such a state is one of the many configuration I^+ states of the p$\bar{n}$ type and is strongly collectivized as a result of the influence of the interaction and the existence of a layer of excess neutrons N - Z [4]. It is separated energywise from the remaining group of I^+ p$\bar{n}$ states and lies close to the analog state. The matrix element of the β decay of this state to the ground state of the target nucleus is close to the matrix element of the β decay of the analog resonance. Similar states with log ft ∿ 3 were apparently observed in Ne^{17}, Ar^{33}, and Ca^{49} [5]. For the purpose of experimentally finding such I^+ resonances, it is of interest to calculate their characteristics, and primarily their positions.

We have calculated the characteristics of these state within the framework of the theory of finite Fermi systems [6] for the medium group of spherical nuclei in the Ge - Ba region. The positions of the isobaric configuration I^+ states of the pn type were determined from the poles of the equation of the Gamow-Teller effective field or bare symmetry $\sigma\tau^+ = V^0$

$$V_{\lambda_1\lambda_2}(\omega) = e_q V^0_{\lambda_1\lambda_2} + \sum_{\lambda\lambda'} \Gamma^{\omega}_{\lambda_1\lambda_2\lambda\lambda'} A_{\lambda\lambda'} V_{\lambda\lambda'}(\omega), \quad (1)$$

$$M^2_{GT} = \sum_{\lambda\lambda'} e_q \chi_{\lambda\lambda'} A_{\lambda\lambda'} V^0_{\lambda\lambda'}, \quad (2)$$

and the matrix elements M_{GT} of the β transition to the ground state of an even-even nucleus A(N, Z) were determined from the residues $\chi_{\lambda\lambda'}$ of the field $V_{\lambda\lambda'}(\omega)$ at the pole point. λ are the quantum numbers of the single-particle scheme, e_q = 0.9 is the effective charge, and Γ^{ω} is the quasiparticle scattering amplitude whose spin-isospin part enters in the problem. Equation (1) describes three main types of configuration isobaric I^+ states: states of the spin-orbit type, $j = \ell + 1/2 \rightarrow j' = \ell - 1/2$, proceeding with spin flip of the charge-exchanging nucleon, states of the j → j type, with flip of the total angular momentum, and states of the spin-orbit type with inverse spin flip ($j = \ell - 1/2 \rightarrow j' = \ell + 1/2$) [3].