INELASTIC SCREENING IN SCATTERING OF HIGH-ENERGY NUCLEONS BY COMPLEX NUCLEI

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The contribution of inelastic screening to the total nucleon-nucleon interaction cross sections at high energies is considered. The effect is connected mainly with the mechanism of diffraction dissociation, amounts to $\sim 2$ - 3% at an energy $E \gtrsim 10$ GeV, and increases logarithmically with increasing energy.

The diffraction theory of multiple scattering [1, 2] is used extensively to describe the interaction of high-energy particles with nuclei. One of the effects not taken into account in this scheme is the inelastic screening connected with the possibility of production of particle beams by the incoming hadron. This phenomenon was discussed in the case of scattering by more complicated nuclei in a number of papers (see, e.g., [3 - 7]).

It should be noted, however, that the estimates obtained so far of the inelastic screening in scattering of hadrons by complex nuclei [4 - 7] were in the main only qualitative, owing to the rather crude assumptions made concerning the mechanism of the inelastic hadron-nucleon interaction. Thus, it was assumed in [4] that all the inelastic amplitudes are pure imaginary, and in [7] only the contribution of the resonances was taken into account.

Much progress was made recently towards the understanding of the mechanism of inelastic hadron-hadron collisions, in connection with the application of the Regge phenomenology to the description of inclusive processes. In particular, it became clear that the Regge phenomenology describes well the inclusive cross sections in the region $M^2/s \ll 1$, where M is the mass of the produced system of particles and s is the square of the energy in the c.m.s. The available information in the inclusive cross sections in the region $M^2/s \ll 1$, and the results obtained in [6] in the analysis of corrections in the deuteron, are used in the present article to calculate the contribution of the inelastic screening to the total cross sections of the interaction of nucleons with complex nuclei ($A \gg 1$).

As shown in [6], in the calculation of inelastic screening in nuclei it is necessary to take into account in the inclusive process $NN \to XN$ only the part corresponding to the diffraction-dissociation mechanism. The contribution of this mechanism to the cross section of the inclusive process $p + p \to X + p$ in the region $M \leq 2$ GeV has a resonant form and was determined in [8] (see also [6]). In the region $M > 2$ GeV, $s \gg m^2$ (m is the nucleon mass), the differential cross section of the diffraction dissociation is well described by the expression [9]

$$\frac{d^2\sigma(t = 0)}{dt\, dM^2} = \frac{c}{M^2} \qquad (1)$$

where the constant $c = 2.4 \pm 0.5$ mb/GeV$^2$ does not depend on s or $M^2$.1) Formula (1) corresponds to a three-pomeron vertex $G_{PPP}$ that does not vanish at $t = 0$.

To calculate the contribution of the diffraction dissociation to the total cross section of the ineraction of nucleons with nuclei, we use the optical model

$$(\nabla^2 + k_a^2)\, \psi_a(r) = \sum_{a'} V_{aa'}(r)\, \psi_{a'}(r), \qquad (2)$$

where $\psi_\alpha$ and $\psi_{\alpha'}$ are the wave functions of the incident nucleon plus nucleus system and the hadron system X plus nucleus, respectively. The optical potential is given by

$$V_{aa'}(r) = -4\pi f_{aa'}(0)\, \rho(r), \qquad (3)$$

where $f_{\alpha\alpha}$, $f_{\alpha\alpha'}$, and $f_{\alpha'\alpha'}$ are the amplitudes of the processes $NN \to NN$, $NN \to XN$, and $XN \to XN$, and $\int \rho(\vec{r}) d^3r = A$. A similar model was used in [10] to consider coherent production of particles on nuclei.

Since the amplitude $f_{\alpha\alpha'}$ is small in comparison with the amplitude $f_{\alpha\alpha}$, it suffices to take $f_{\alpha\alpha'}$ into account in the first non-vanishing order of perturbation theory. The main contribution to the inelastic shadow correction is made by small masses, $M^2/s < 1/mR$, where R is the radius of the nucleus. We assume that in this mass interval the total cross section for the interaction of the hadron system X with the nucleon does not depend on the mass M, and is close to the total cross section of the NN interaction. We use also the fact that the amplitude of the diffraction dissociation is pure imaginary and is the same for pp, pn, and nn interactions. Solving Eq. (2) in the eikonal approximation, we obtain the amplitude of elastic scattering of a nucleon by a nucleus. We express the cross section in terms of the amplitude at zero angle. In this case, the contribution of the inelastic screening to the total nucleon-nucleus interaction cross section is given by

$$\Delta\sigma = -4\pi \int d^2 b \int_{(m+m_\pi)^2}^{(\sqrt{s}-m)^2} dM^2 \frac{d^2\sigma(t=0)}{dt\, dM^2} \exp\left[-\frac{1}{2}\sigma T(b)\right] |F(q_L, b)|^2, \tag{4}$$

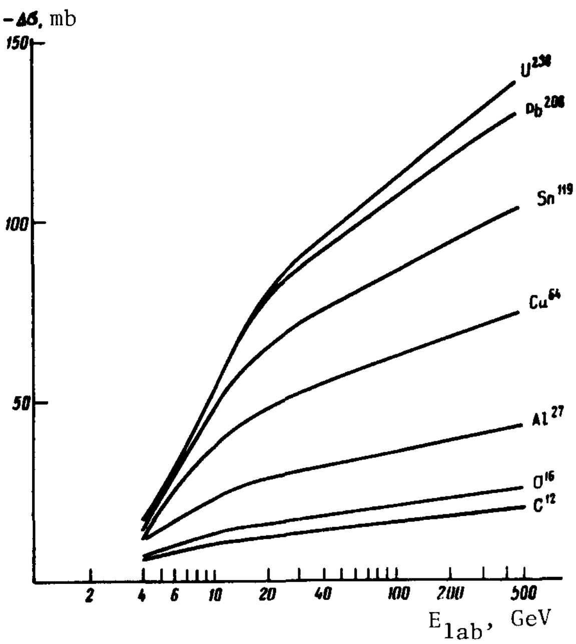
where $T(b) = \int_{-\infty}^{+\infty} \rho(\vec{b}, z)dz$, $q_L$ is the longitudinal momentum transfer in the production of the mass M, $q_L = (M^2 - m^2)m/s$, and the form factor

$$F(q_L, b) = \int_{-\infty}^{+\infty} \rho(b, z) e^{iq_L z} dz \tag{5}$$

limits the integration over the mass M to the region $q_L R = m^2 mR/s \lesssim 1$. At large values of the parameter $\sigma A/2\pi R^2$ (black nucleus), the correction $\Delta\sigma$ can be represented in the form

$$\Delta\sigma = -\left(\frac{4\pi R}{\sigma}\right)^2 \left[\gamma_0 + c \ln \frac{s}{m^3 R}\right],$$

where c is determined by expression (1), and $\gamma_0$ is determined by the differential diffraction-dissociation cross section $d^2\sigma(t = 0)/dtdM^2$, integrated over the region of small masses, $M \lesssim 2$ GeV. Just as in scattering by a deuteron, the inelastic shadow correction $\Delta\sigma$ increases logarithmically with energy, this being a consequence of the slow decrease of $d^2\sigma(t = 0)/dtdM^2$ with increasing M. As already mentioned, the coefficient in front of the logarithm is determined by the expression (1), i.e., by the quantity $d^2\sigma/dtdM^2$ as $t \to 0$. Thus, for example, if $d^2\sigma/dtdM^2$ were to vanish at small t like $c_1 t$, then this coefficient would be proportional to $c_1/R^2$. The existing experimental data on the reaction $p + p \to p + X$ indicate that $d^2\sigma/dtdM^2$ increases with decreasing t down to $|t| = 0.05$ GeV$^2$ and that there are apparently no grounds for expecting vanishing at small t.




Numerical estimates of the correction $\Delta\sigma$ were made for a Gaussian parametrization of the density $\rho(r) = (A/\pi^{3/2}R^3)\exp(-r^2/R^2)$, $R = 0.7A^{1/3}$F, for the nuclei $C^{12}$ and $O^{16}$, and for a constant density with radius $R = 1.1A^{1/3}$ F for heavier nuclei (see the figure). The quantity $\Delta\sigma$ makes a contribution $\sim 2 - 3\%$ to the total cross sections at $E > 10$ GeV, a contribution noticeably larger than the accuracy ($\sim 0.5\%$) with which the total cross sections of nucleon-nucleus interactions are being measured at the present time.

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1)The constant c, corresponding to the results of [9], should be increased 20% if the data on $d^2\sigma/dtdM^2$ in the region of small $t \sim 0.05$ GeV$^2$ are taken into account. The authors thank A. B. Kaidalov for this remark.

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## INCREASE OF TOTAL CROSS SECTIONS AND SLOPE OF DIFFRACTION PEAK

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Predictions for the behavior of the total cross sections are obtained on the basis of the available experimental data on hadron-hadron collisions and the general principles of quantum field theory.

This article1) examines the possibility that the growth of the total $K^+p$-interaction cross section, observed at Serpukhov [1], and the rapid growth of the pp cross section recently observed at CERN [2], may have the same physical nature. Experimental consequences for the verification of this possibility are indicated. It is shown that the behavior of the slope parameter of the diffraction peak does not contradict the considered mechanism.

The CERN measurements have shown that the total cross section of the pp interaction begins to increase starting approximately with 100 GeV, and its behavior in the range 50 - 1500 GeV is given by

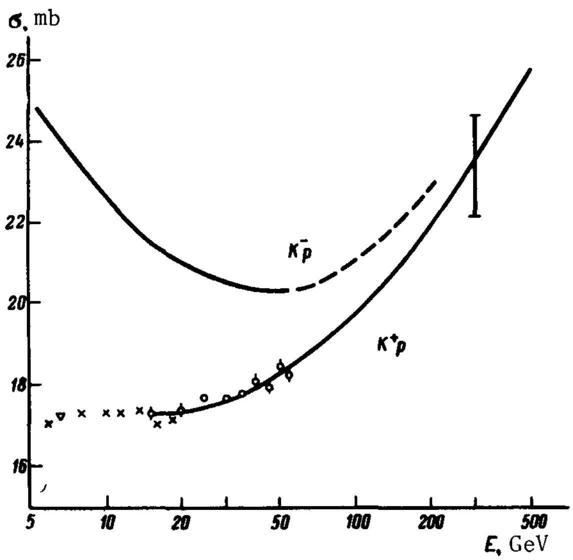
$$\sigma = \sigma_0 + \sigma_1 [\ln (E/E_0)]^\nu , \qquad (1)$$

where $\sigma_0 = 38.4 \pm 0.3$ mb, $E_0 = 100$ GeV, $\sigma_1 = 0.9 \pm 0.3$ mb, and $\nu = 1.8 \pm 0.4$. The last number does not contradict the assumption that the cross section reaches the Froissart limit [3]. The parameter $\sigma_1$ decreases to 0.7 if the terms that decrease with energy are taken into account in (1). For concreteness, we consider

$$\sigma_1 = 0.7 \pm 0.2 \text{ mb}, \quad \nu = 2. \qquad (2)$$

The Froissart limit, as is well known, corresponds to saturation of the partial waves up to the maximum moment compatible with analyticity. It is natural to assume that this mechanism, if it operates at all, is universal for all elastic hadron processes and has an asymptotic value $\sigma_1 \ln^2 E$ as $E \to \infty$ for all total hadron cross sections.

In the case of finite energies, of course, the next terms in the asymptotic series, which depend on the reaction, are important. In a final




Predicted behavior of total $K^+p$ cross section in the case of the universal Froissart mechanism. The vertical bar at 300 GeV corresponds to the errors of the parameter $\sigma_1$ (formula (2)) and of the $K^+p$ cross section [1]. The tentative behavior of the total $K^-p$ cross section is also indicated.