NN-INTERACTIONS IN THE POLE APPROXIMATION

P. SMRZ and HUANG TSU-CHAN

Joint Institute for Nuclear Research

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Momentum spectra of recoil protons in NN interactions are calculated on the basis of the pole approximation. Results of the calculations are presented for primary nucleon energies from 2.8 to 9 GeV. A comparison with available experimental data reveals no significant discrepancies. The characteristic shape of the curves does not depend strongly on the energy, but the shapes of the spectra for pp and pn collisions differ noticeably. This is due to a difference of the isospin coefficients and is thus a characteristic feature of one meson exchange.

ALTHOUGH the pole approximation has been employed many times for a description of inelastic NN collisions, the calculations were made for only several special cases. It was assumed, in particular [1,2] that the particles are produced following the decay of two "isobars," the masses of which can assume any value allowed by the conservation laws. In addition, only two-jet diagrams were considered [see Fig. 1 (1)], and the contribution of diagrams with one unexcited nucleon [Fig. 1 (2)] was neglected. On the other hand, the experimental data indicate that one-jet diagrams may even play a decisive role 1) [3]. In our calculations we took into account both types of diagrams and substituted in the vertices the experimental data on πN collisions. The principal property of one-meson exchange is the difference between the spectra of the recoil proton in pp and pn interactions. This difference, however, has been little investigated experimentally, and comparison with experiment has therefore been made only for pp interaction at 3.5 GeV, for which satisfactory agreement is obtained.

The momentum spectrum of the recoil nucleon of the process of Fig. 1 (1) is calculated from the formula

$$\frac{\partial\sigma^{(1)}}{\partial p}=\frac{1}{(2\pi)^3}\frac{p^2}{2p_U^2U^2}\int_{(m+\mu)^2}^{(U-m-\mu)^2}dW_2^2\int_{(m+\mu)^2}^{(U-W_2)^2}dW_1^2$$
$$\times\int_{-1}^{+1}d(\cos\vartheta)\frac{\omega_{W_1}}{\omega}F_{W_1}(k_{W_1},\cos\vartheta_{W_1})$$
$$\times\left(\frac{1}{\Delta_{min}^2+\mu^2}-\frac{1}{\Delta_{max}^2+\mu^2}\right)p_{W_2}W_2\sigma(W_2), \qquad (1)$$

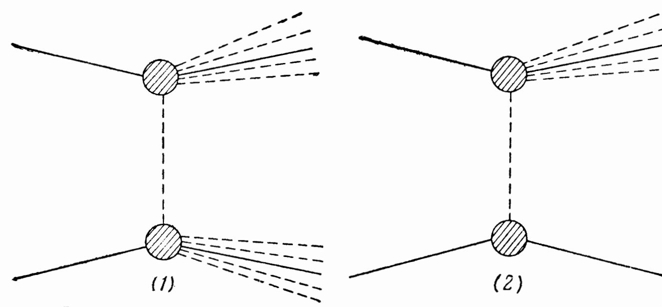

FIG. 1. Principal types of NN interactions in the one meson approximation.

where W—total energy in the c.m.s. of the πN vertex; U—total energy in the NN c.m.s.; p_U—momentum of the primary particle in the πN c.m.s.; $\sigma(W)$—total cross section of the πN interaction, which depends on W; ω and p—energy and momentum of the recoil nucleon in the c.m.s. of the colliding nucleons:

$$\omega_{W_1}=\gamma\omega-\sqrt{\gamma^2-1}\;p\cos\vartheta,\quad k_{W_1}=\sqrt{\omega_{W_1}^2-m^2},$$
$$\Delta^2_{max,\,min}=-W_1^2-W_2^2+UE\pm 2p_UP,$$
$$\cos\vartheta_{W_1}=(\omega-\gamma\omega_{W_1})/k_{W_1}\sqrt{\gamma^2-1},$$
$$\gamma=\frac{U^2+W_1^2-W_2^2}{2UW_1},\qquad E=\frac{U^2+W_1^2-W_2^2}{2U},$$
$$P=\sqrt{E^2-W_1^2}. \qquad (2)$$

The momentum spectrum of the nucleon from the upper vertex of the process of Fig. 1 (2) is calculated from the formula

$$\frac{\partial\sigma_u^{(2)}}{\partial p}=\frac{g^2}{4\pi}\frac{p^2}{2p_U^2U^2}\int_{(m+\mu)^2}^{(U-m-\mu)^2}d(W^2)$$
$$\times\int_{-1}^{+1}d(\cos\vartheta)\frac{\omega_W}{\omega}F_W(k_W,\cos\vartheta_W)$$
$$\times\left\{\ln\frac{\Delta_{max}^2+\mu^2}{\Delta_{min}^2+\mu^2}-\mu^2\frac{\Delta_{max}^2-\Delta_{min}^2}{(\Delta_{max}^2+\mu^2)(\Delta_{min}^2+\mu^2)}\right\}, \qquad (3)$$

1)It must be noted that this question has not yet been solved, inasmuch as there are many other experimental investigations (see, for example[4]) which yielded contrary results.

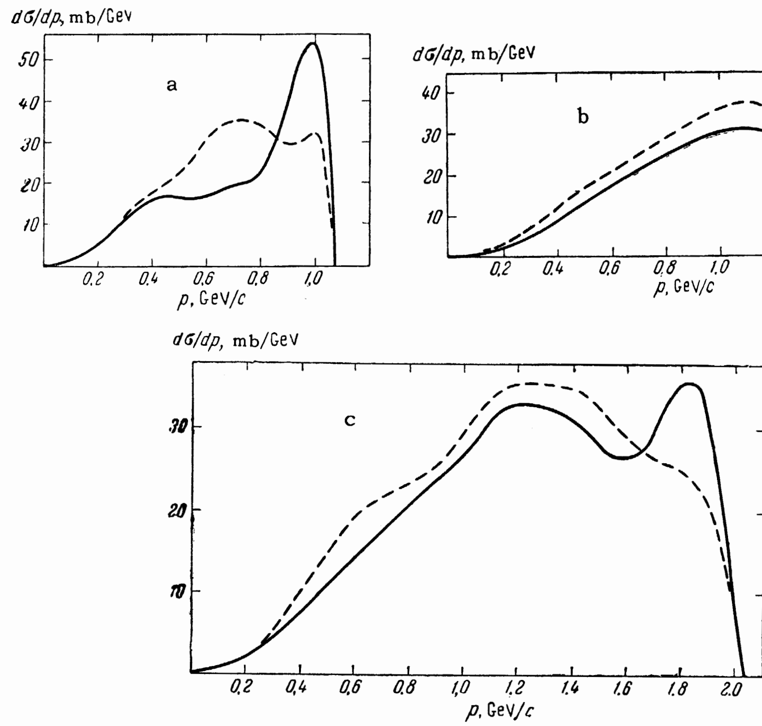

FIG. 2. Momentum spectra of the recoil proton in the c.m.s. at a primary proton *l*.s. energy: a – 2.8, b – 6 and c – 9 GeV. The solid curves correspond to pp collisions and the dashed lines to pn collisions.

where all the quantities involved are determined from (2), in which we must put $W_2 = m$ and $W_1 = W$. Finally, the momentum spectrum of the nucleon from the lower vertex of the diagram 1 (2) is given by

$$\frac{\partial \sigma_l^{(2)}}{\partial p} = \frac{g^2}{4\pi} \frac{1}{p_U{}^2 U} p_W W \sigma_{\pi N}(W) \frac{p}{\omega}$$
$$\times \left\{ \ln \frac{\Delta_{max}^2 + \mu^2}{\Delta_{min}^2 + \mu^2} - \mu^2 \frac{\Delta_{max}^2 - \Delta_{min}^2}{(\Delta_{max}^2 + \mu^2)(\Delta_{min}^2 + \mu^2)} \right\}. \quad (4)$$

In formulas (1) and (3) the function $F_W(k_W, \cos\vartheta_W)$ denotes the distribution over the momentum and angle of the recoil nucleon in πN collisions at a c.m.s. energy W. Since the joint distribution over the momentum and angle are not known experimentally, we have used the approximation

$$F_W(k_W, \cos\theta_W) = \Phi(W, k_W)\Theta(W, \cos\theta_W)\sigma_{\pi N}(W),$$

where Φ and Θ denote the experimental momentum and angular spectra normalized to unity. The isospin coefficients were taken into account separately for each concrete type of interaction. The virtuality of the intermediate meson was neglected, and the form factor of the nucleon was assumed equal to unity in the entire region of integration with respect to Δ^2.

Figure 2 shows the calculated c.m.s. momentum spectra of the recoil proton for primary-proton energies 2.8, 6, and 9 GeV. Figure 3 shows a comparison with the experimental histogram published by Giserchio and Kalbach[5]. The calculated total cross sections increase with increasing energy, and for the energies 6 and 9 GeV they already exceed the experimental values by several times (for example, for pp collisions at 9 GeV we obtain $\sigma_{pp}^{tot} = 92$ mb).

The reason lies in the approximations indicated above, particularly in the independence of the total cross sections of the πN interactions of Δ^2. However, as was shown by Barashenkov et al.[6], the form of the momentum spectrum is practically independent of the cutoff at large Δ^2, so that a more thorough comparison of the curves in Fig. 2 with experiment is desirable. The principal contribution is always made here by the one-jet processes [Fig. 1 (2)]. At 9 GeV energy they even comprise 73% of the total cross section. This property of

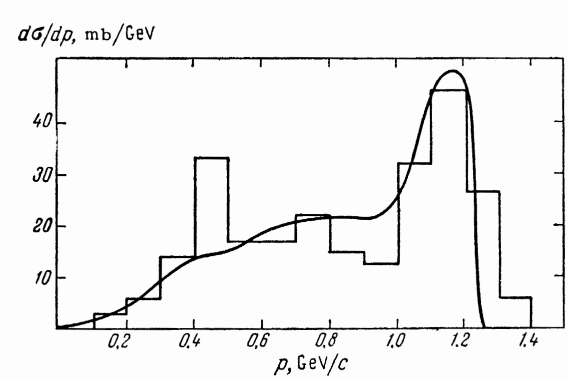

FIG. 3. Comparison of the momentum spectrum of the recoil proton for 3.5 GeV energy with the experimental histogram[5].

one-jet processes leads to a difference between the recoil-proton spectra in pp and pn collisions. The isospin coefficients obtained upon selection of the proton states of the recoil nucleon cause the virtual πN scattering to occur in pp interactions essentially at $T = 3/2$ and in pn interactions, to the contrary, predominantly at $T = 1/2$. This leads to a presence of a high-energy maximum in pp collisions, which is less strongly pronounced in pn collisions.

An experimental observation of the difference in the momentum distributions of the recoil proton in pp and pn collisions would yield further information on whether the one-jet processes play a principal role in nucleon nucleon collisions at medium energies. Since the theoretical difference in the momentum distributions is connected only with the assumption that the form factors are independent of Δ^2, and remains the same for any form of the dependence $\sigma_{\pi N}(\Delta^2)$, a positive result of the experiment would make it possible to conclude unambiguously that the excessive theoretical values of the cross sections are connected only with failure to take account of the dependence of $\sigma_{\pi N}$ on Δ^2.

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