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III-7-9. On Interactions of π-Mesons and Nucleons at High Energies

("Target Mass" in One-Meson-Exchange Interaction)

N. G. BIRGER and YU. A. SMORODIN

P. N. Lebedev Physical Institute, Academy of Sciences of the USSR, USSR

While considering the inelastic interactions of high energy particles the value M_t—the effective target mass—was introduced[1)]

$$M_t=\Sigma(E_i-P_i\cos\theta_i)$$
$$=M_n-(E_\delta-P_\delta\cos\theta_\delta) \qquad (1)$$

E_i, P_i, θ_i are the total energy, momentum and angle of all emitted particles excluding the recoil nucleon which have the corresponding values $E_\delta, P_\delta, \theta_\delta$.

When a fast particle interacts with a system of weakly coupled particles, M_t has a simple physical meaning being a mass of the part of the target particle which participates in the interaction.

On the other hand[2)] M_t is equal to K_s—the coefficient of the inelasticity of the target particle—in the coordinate system coupled with the incident particle.

Earlier it was noted that there is a maximum at the values M_t close to pion mass μ in the experimentally observed M_t-distribution for both N-N and π-N interactions at various energies[3)-6)]. Such maximum may be naturally connected with the peripheral one-meson interaction.

It was proposed that the process corresponding to the diagram of Fig. 1 made the main contribution to the peripheral one-meson interactions and the interference of that process with more complicated processes was neglected.

In general, the process with simultaneous exitation of both vertices of the diagram can be considered. However, the presence of the sharp maximum in M_t-distributions and considerable part of the asymmetrical N-N interactions[3)] indicates the great contribution of the processes with little excitation of the left vertex. In that case one may try to calculate M_t-spectrum in the region of the maximum by the method of Chew and Low[7)].

It can be shown for sufficiently high energy that M_t and variables ω^2 and Δ^2 [7)] satisfy the relation

$$M_t=\frac{\omega^2+\Delta^2-\mu_1^2}{2P_0}$$

where μ_1 is the mass of the incident particle and P_0 is its momentum. Then

$$\frac{d\sigma}{dM_t}=\frac{f^2}{2\pi P_0\mu^2}\int_{\omega^2_{\min}}^{\omega^2_{\max}}\frac{2P_0M_t-\omega^2+\mu_1^2}{(2P_0M_t-\omega^2-\mu^2+\mu_1^2)}$$
$$\times[\omega^4-2\omega^2(\mu_1^2+\mu^2)+(\mu_1^2-\mu^2)^2]^{1/2}$$
$$\times\sigma_{\mu,\mu_1}(\omega^2,\Delta^2)d\omega^2 . \qquad (2)$$

The kinematically allowed regions of the variables ω^2 and Δ^2 are shown in Fig. 2.

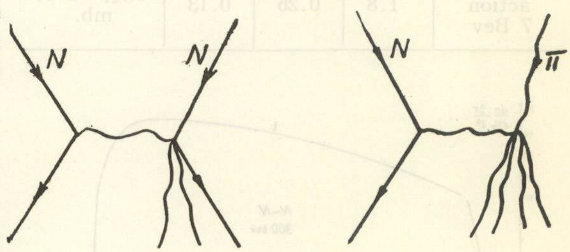

Fig. 1.

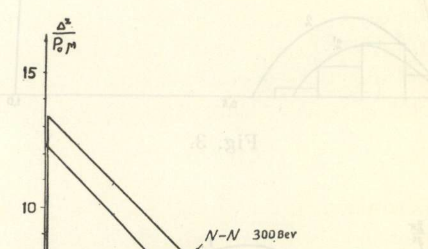

Fig. 2.

The integration was made for N-N interactions at the energy 300 GeV and for π-N interactions at the energy 7 GeV in two assumptions on the value of $\sigma_{\mu,\mu_1}(\omega^2, \Delta^2)$.

(1) $\sigma_{\mu,\mu_1}(\omega^2, \Delta^2)=$const. for all the kinematically allowed regions of the variables ω^2 and Δ^2.

$$(2)\quad \sigma_{\mu,\mu_1}(\omega^2,\Delta^2)\begin{cases} =\text{const.} & \text{at } \Delta^2\le\Delta_k^2 \\ =0 & \text{at } \Delta^2>\Delta_k^2 \end{cases}$$

The results of the integrations are given in Fig. 3 and Fig. 4 for some values of Δ_k^2 ($\Delta_k^2=9\mu^2$—curve 2, $\Delta_k^2=16\mu^2$—curve 2′).

Table I lists the data for the total cross-sections of one-meson interactions (OMI).

It is evident from the table that one can not obtain the agreement with the experiment using the method of Chew and Low without special assumption on the dependence of σ_{μ,μ_1} upon ω^2 and Δ^2 *.

Table I. Ratio $\frac{\sigma_{OMI}}{\sigma_{\mu\mu 1}}$

	Calculation 1	2	2′	Experiment
N-N interaction 300 Bev	7.3	0.27	0.13	0.5–0.7[3]
π-N interaction 7 Bev	1.8	0.26	0.13	σ_{OMI} =5–10 mb.

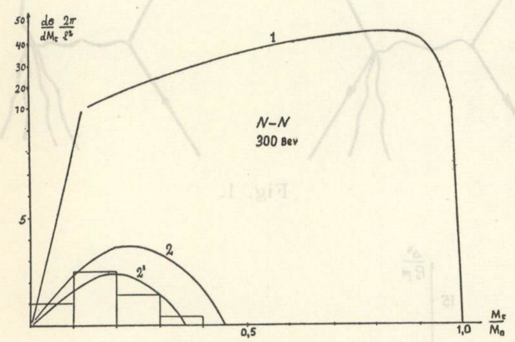

Fig. 3.

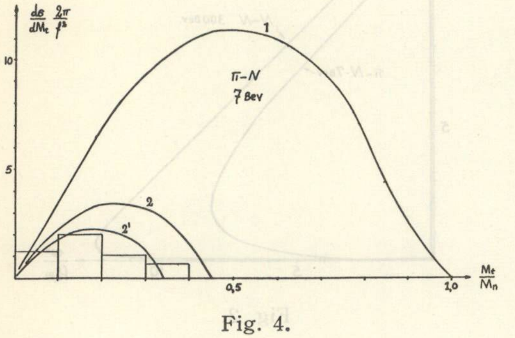

Fig. 4.

Experimentally observed M_t-distribution[3),4)] is shown in Fig. 3 and Fig. 4 by the histograms.

The calculation made in the variant 2′ agrees with the experimental data for N-N interactions at 300 Bev and π-N interactions at 7 Bev.

However, in this case (see Table I) $\sigma_{\pi N}$ for the interaction of the virtual pion is equal to 150 mb, which is five times greater than the known cross section for inelastic π-N interaction.

The $\sigma_{\pi N}$ amounts to 30 mb at the value $\Delta_k^2=25\mu^2$. In this case experimental M_t-distribution is considerably sharper than calculated. The maximum of the theoretical curve lies at a greater M_t value than experimental one.

From formula (2) it follows that for π-N interactions with sufficiently low Δ^2, M_t-distributions practically repeat the ω^2-distribution for some events ($\omega^2\approx 2P_0M_t$). The maximum at $M_t\sim\mu$ which is observed experimentally leads to the maximum in the ω^2-distribution in the region $\omega^2{}_0=2P_0\mu$.

This value of energy at the maximum of distribution corresponds to a rough model in which the interaction with π-meson of the pion cloud of nucleon is treated as if π-meson in the moment of collision were a real free particle with a low momentum.

In the recent papers[10),11)] more precise distributions of the number of the π-N interactions at energies of ~1 and 2 GeV versus ω^2 were obtained. The position and width of maxima observed do not contradict the above model while calculations according to Chew and Low agree worse with the distributions observed.

The authors believe that $\pi\pi$-resonance does exist which accounts for the results obtained. However, the dependence of the maximum position upon the primary energy of π-mesons contradicts this supposition (if there are no experimental errors).

* Identical results were obtained in the papers[8)] and[9)] where one-meson interactions with simultaneous excitation of both vertices in the diagram of Fig. 1 were considered.

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Discussion

Kobayakawa, K.: I would like to know whether you have or not any special reason for your choice in the form of the virtual cross section which is constant in some region. I feel that the virtual cross section has very strong dependence on Δ^2 and ω^2.

Smorodin, Yu. A.: It is evident that one cannot obtain the agreement with the experiment using the one meson exchange model of interaction without special assumptions about the dependence of σ_{μ,μ_1} on Δ^2 and ω^2. The simplest assumption also does not show a good agreement with experimental data. It is possible, may be, to select the shape of dependence of σ_{μ,μ_1} on Δ^2 and ω^2 to get a good agreement. But it seems to be only a substitute for the theoretical explanation.

Namiki, M.: Could you expect more maxima other than that corresponding to pion target in the M_t-distribution?

Smorodin: I think that the second maximum in M_t-distribution, if it exists corresponds to target mass different from the one pion mass. Experimentally the existence of the second maximum in M_t-distribution has not established, but there is some evidence[4] in favor of its existence.

Zatsepin, G. T.: The kinematics of observed nucleon-nucleon interactions leads to diagrams different from yours. It is better to use such diagrams shown in Fig. A for the intermediate energy region. For higher energies the diagram of Fig. B may be responsible.

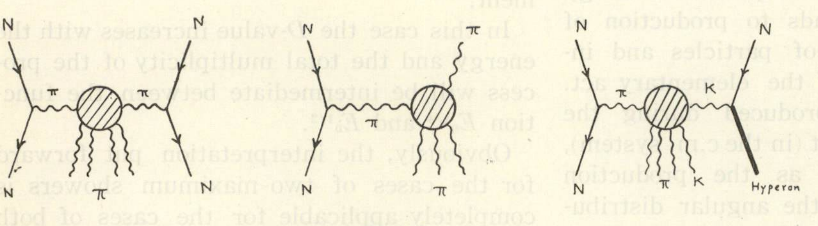

Fig. A

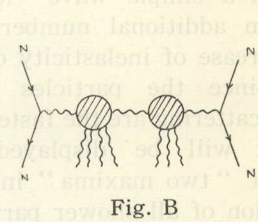

Fig. B

Smorodin: I think that in the present stage of quantum theory it is impossible to do such calculations without a great number of assumptions.