POSSIBLE ROLE OF VECTOR MESONS IN ELASTIC SCATTERING OF HIGH-ENERGY PIONS AND PROTONS

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We calculate the contribution that a pole diagram due to vector particle exchange makes to elastic scattering of π mesons and protons on protons and also on π mesons at high energies. Good agreement with experiment is obtained.

MANY recent papers are devoted to the application of the one-meson approximation to inelastic πp and pp collisions at high energies. This approximation yields a very low value for the elastic-collision cross section at high energies. In the present note we calculate the contribution that the pole diagram due to the exchange of one vector particle B makes to the elastic scattering of pions and protons on protons, and also pions on pions at high energies (greater than 1 BeV).

Let us introduce the interactions between the vector field and the nucleon or pion fields in the form

$$a : \bar{\psi}(x)\gamma_\mu\psi(x)B_\mu(x):,$$
$$c: \left(\varphi^+(x)\frac{\partial\varphi(x)}{\partial x_\mu} - \frac{\partial\varphi^+(x)}{\partial x_\mu}\varphi(x)\right)B_\mu(x): . \qquad (1)$$

Then the differential cross section for proton-proton, pion-proton, or pion-pion elastic scattering at high energies can be written down in the following manner:

$$\sigma_{pp}(\theta) = \left(\frac{a^2}{4\pi}\right)^2\frac{2(1+\gamma)^2}{m^2\gamma^2(\gamma+2)}\frac{1}{(1-\cos\theta+\delta)^2},$$
$$\sigma_{\pi p}(\theta) = \frac{a^2}{4\pi}\frac{c^2}{4\pi}\frac{1+2\gamma}{m^2\gamma^2}(1-\cos\theta+\delta')^{-2},$$
$$\sigma_{\pi\pi}(\theta) = \left(\frac{c^2}{4\pi}\right)^2\frac{2}{m\mu\gamma}(1-\cos\theta+\delta'')^{-2}, \qquad (2)$$

where

$$\gamma = \frac{E_{\text{kin}}}{m}, \qquad \delta = \frac{\mu_2^2}{m^2\gamma}, \qquad \delta' = \frac{\mu_2^2(1+2\gamma)}{2m^2\gamma^2}, \qquad \delta'' = \frac{\mu_2^2}{\mu m\gamma},$$

m, μ, and μ_2 are the rest masses of the proton, pion, and the vector particle B, respectively, E_{kin} is the kinetic energy of the incoming particle in the laboratory system, and θ is the scattering angle in the c.m.s.

The total elastic-scattering cross sections, obtained from (2) by integration, and the total cross sections (cross section of the elastic interaction plus the cross section of the inelastic interaction) obtained from the optical theorem, are independent of the energy at high energies and are equal to

$$\sigma_{el}(pp) = \left(\frac{a^2}{4\pi}\right)^2\frac{4\pi}{\mu_2^2}, \qquad \sigma_{el}(\pi p) = \frac{a^2}{4\pi}\frac{c^2}{4\pi}\frac{4\pi}{\mu_2^2},$$
$$\sigma_{el}(\pi\pi) = \left(\frac{c^2}{4\pi}\right)^2\frac{4\pi}{\mu_2^2}, \qquad \sigma_t(pp) = \frac{2a^2}{\mu_2^2},$$
$$\sigma_t(\pi p) = 2\,ac/\mu_2^2, \qquad \sigma_t(\pi\pi) = 2c^2/\mu_2^2. \qquad (3)$$

The cross sections themselves are very sensitive to the choice of the constants a, c, and μ_2. However, the total cross sections are connected by relations that are independent of a, c, and μ_2. These relations are readily obtained from formulas (3) and have the form

$$\sigma_{el}(\pi p) = \sqrt{\sigma_{el}(\pi\pi)\,\sigma_{el}(pp)}, \qquad \sigma_t(\pi p) = \sqrt{\sigma_t(\pi\pi)\,\sigma_t(pp)},$$
$$\sigma_t(\pi p)/\sigma_t(pp) = \sqrt{\sigma_{el}(\pi p)/\sigma_{el}(pp)}. \qquad (4)$$

Within the limits of the existing experimental data[1], the last relation in (4) is well satisfied. From the first two, knowing the total cross sections of the pp and πp interactions, we can estimate the cross section of the $\pi\pi$ interaction. Taking

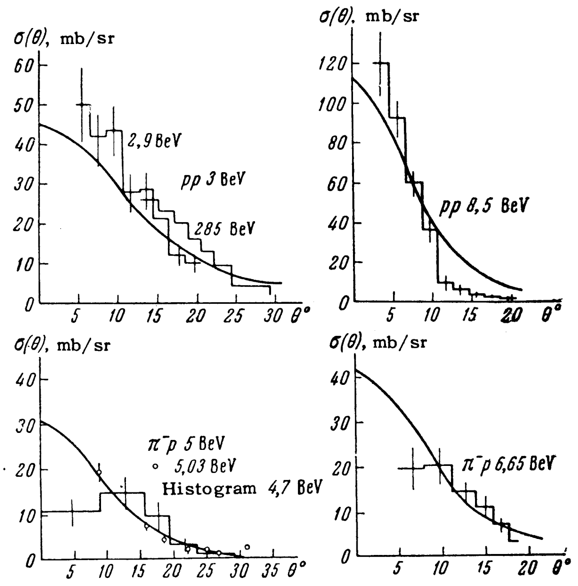
$$\sigma_{el}(pp) = 10\text{ mb}, \qquad \sigma_{el}(\pi p) = 7\text{ mb}, \qquad \sigma_t(pp) = 40\text{ mb}, \qquad \sigma_t(\pi p) = 28\text{ mb},$$

we obtain for the total $\pi\pi$-interaction cross sections

$$\sigma_{el}(\pi\pi) = 5\text{ mb}, \qquad \sigma_t(\pi\pi) = 20\text{ mb}.$$

We calculated the pp and πp elastic scattering differential cross sections from (2) and the total pp, πp, and $\pi\pi$ interaction cross sections from (3) for the following parameters:

$$a^2/4\pi = 0.775, \qquad c^2/4\pi = 0.388, \qquad \mu_2^2 = 8.85\mu^2.$$



The following values were obtained for the total cross sections:

$$\sigma_{el}(pp) = 15 \text{ mb}, \quad \sigma_{el}(\pi p) = 7.5 \text{ mb}, \quad \sigma_{el}(\pi\pi) = 4 \text{ mb},$$
$$\sigma_t(pp) = 40 \text{ mb}, \quad \sigma_t(\pi p) = 28 \text{ mb}, \quad \sigma_t(\pi\pi) = 20 \text{ mb},$$

The figure shows the theoretical and experimental data for the differential cross sections of elastic pp scattering at 3 and 8.5 BeV and elastic $\pi^- p$ scattering at 5 and 6.65 BeV. The experimental data on pp scattering at 2.9 and 8.5 BeV were taken from the papers of Azimov, Do In Seb et al[2] and Do In Seb, Kirillova et al[3], while the remainder were taken from the review of Barashenkov[4]. As can be seen from the figure, the agreement between theory and experiment is fully satisfactory.

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[1] V. S. Barashenkov and V. M. Mal'tsev, Preprint R-724, Joint Inst. Nuc. Res., 1961.

[2] Azimov, Do In Seb, Kirillova, Khabibulina, Tsyganov, Shafranova, Shakhbazyan, and Yuldashev, JETP **42**, 430 (1962), Soviet Phys. JETP **15**, 299 (1962).

[3] Do In Seb, Kirillova, Markov, Popova, Silin, Tsyganov, Shafranova, Shakhbazyan, and Yuldashev, JETP **41**, 1748 (1961), Soviet Phys. JETP **14**, 1243 (1962).

[4] V. S. Parashenkov, Preprint R-817, Joint Inst. Nuc. Res., 1961.

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