LARGE ANGLE ELASTIC SCATTERING AT HIGH ENERGIES AND THE QUARK MODEL

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A quark model is proposed for the large angle elastic scattering of elementary particles. The model explains the main features of the baryon-baryon and baryon-antibaryon scattering.

In this paper we investigate the experimental consequences of the assumption that the large-angle two-body scattering of hadrons at high energies may be considered as an incoherent interaction of two systems composed of quarks and antiquarks. Our starting point is the model of Kawaguchi, Sumi and Yokomi [1]. Since, however, we assume that the interaction is incoherent, we add cross-sections instead of amplitudes. This brings in serious quantitative modifications.

To explain the idea consider elastic pp scattering. In the initial state there are six quarks labelled from 1 to 6 (see Fig. 1). The final state can be realized by the twelve quark configurations shown in Fig. 1. Similarly nine final configurations are found for pn scattering and one for $p\bar{p}$ scattering. They are also drawn in Fig. 1. The fundamental assumption of the model is that for the scattering at 90° in the centre of mass system, when the momentum transfer is very large, all the accessible quark configurations appear with approximately the same probability in the final state. This approximate equality between the probabilities follows from the assumption that the quarks scatter independently from each other. The assumption that processes with and without quark transfer have equal probabilities is of course plausible only for collisions with high momentum transfer.

As seen from Fig. 1 the model predicts at 90°

$$\sigma_{pp} : \sigma_{np} : \sigma_{p\bar{p}} = 12 : 9 : 1 \tag{1}$$

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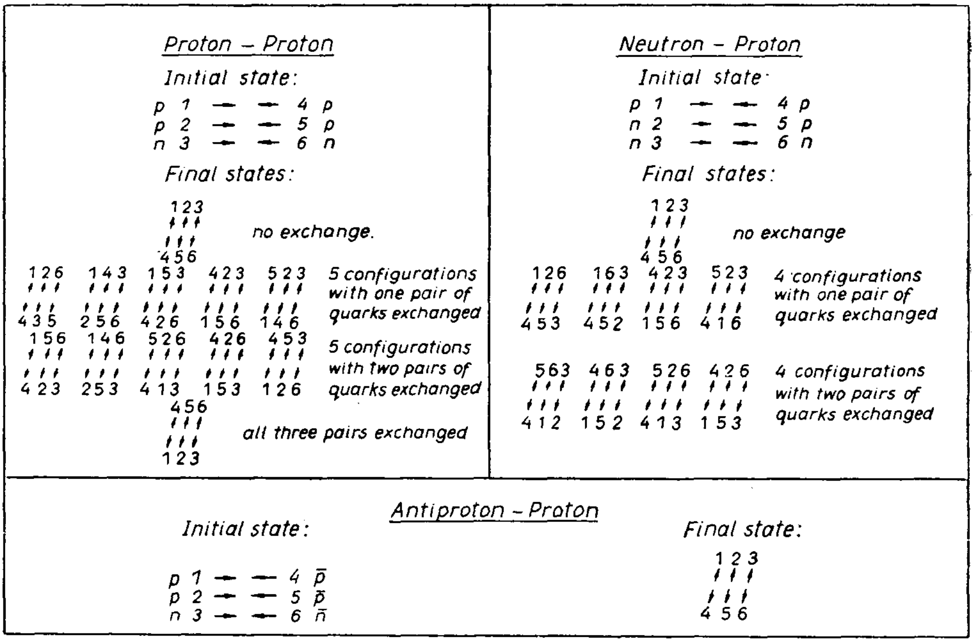

Fig. 1. Quark configurations in pp, np, and $\bar{p}p$ elastic scattering

Thus it is predicted that the cross-section for the large angle elastic $p\bar{p}$ scattering is by about an order of magnitude smaller than the corresponding cross-section for pp or pn scattering. The cross-sections for pp and pn scattering are expected to be of the same order.

Experimentally the ratio of the pp to pn elastic differential cross-section at 90° was estimated by Perl [2]. Using data in the 3–7 GeV/c primary momentum range he found

$$R = 1.01 \pm 0.09 \tag{2}$$

in rough agreement with our result. The 6 GeV/c $p\bar{p}$ data of Rubinstein *et al.* [3] are compared with corresponding pp and pn data in Fig. 2. The nucleon-antinucleon cross-section at 90° is indeed by an order of magnitude smaller than the nucleon-nucleon one.

Applying similar arguments to meson-baryon scattering one finds

$$\sigma_{\pi^+p} : \sigma_{\pi^-p} = 3 : 2 \tag{3}$$

$$\sigma_{K^+p} : \sigma_{K^-p} = 3 : 1 \tag{4}$$

We would like to add a few comments about the assumptions which we used.

a) The approximate equality between the probabilities for processes with and without quark transfer can be justified only if there are no significant correlations between the quarks, which before the scattering were bound together. As we already remarked this assumption is plausible only at very high momentum transfers. At small momentum transfers (*i. e.* low energies since we are discussing the scattering at 90°) such correlations between quarks probably do exist and consequently not all of the final states shown in Fig. 1 are

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equally probable. It seems, in particular, that the states $\overset{1}{\uparrow}\overset{2}{\uparrow}\overset{3}{\uparrow}$, $\overset{4}{\uparrow}\overset{5}{\uparrow}\overset{6}{\uparrow}$ should be preferred to the others. This leads to the conclusion that the $\sigma_{pp} : \sigma_{p\bar{p}}$ ratio in the 90° region should increase with energy until a limit given approximately by formula (1) is reached. The existing experimental data support this statement (see *e. g.* [4]).

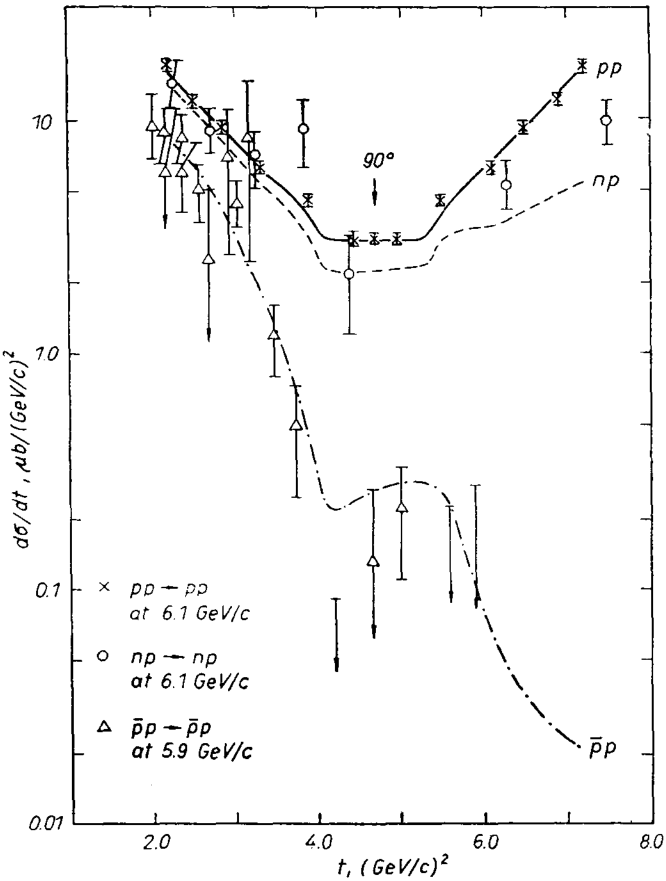

Fig. 2. Experimental cross-sections for 6 GeV/c *pp* [6], 6.1 GeV/c *np* [2], and 5.9 GeV/c $\bar{p}p$ [3] large angle elastic scattering. Curves represent the fits to the data.

b) Since we have no information about the relative phases of the amplitudes corresponding to the final states shown in Fig. 1, we add probabilities and not amplitudes. This should be understood as only a first rough guess and may be subjected to change. One should bear in mind that this procedure *does not* imply any strong fluctuations in the cross-sections as functions of energy or scattering angle.

c) Qualitatively similar results for 90° scattering could be obtained using the quark version of the statistical model, which was proposed by Koba [5].

In order to make our model a little more quantitative we tried to fit the existing experimental data at highest available momenta. To this end we made the following two further assumptions:

1. The probability of reaching any final configuration is expressed as a product of three factors. Each factor corresponds to the probability of finding one incident quark in the given final state. This probability will be denoted further by $\alpha(\theta)$.

2. For a fixed energy $\alpha(\theta)$ is supposed to depend only on the scattering angle. Thus it depends neither on the kind of the incident quark, nor on the nature of the other quarks involved in the scattering process.

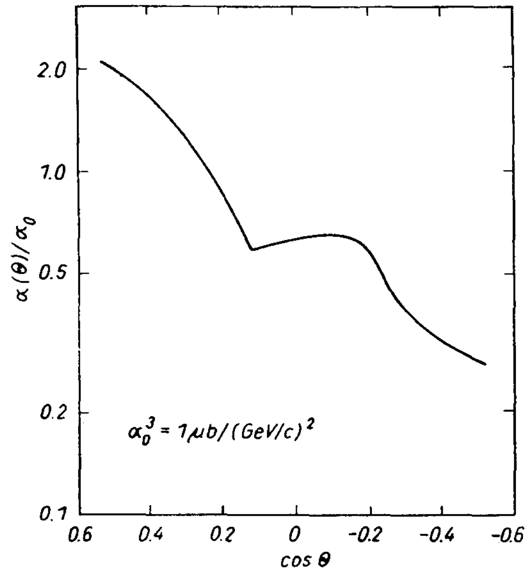

Fig. 3. The function $\alpha(\theta)$ used to fit the data

With these assumptions it is seen from Fig. 1 that

$$\sigma_{pp} = \alpha^3(\theta)+5\alpha^2(\theta)\,\alpha(\pi-\theta)+5\alpha(\theta)\,\alpha^2(\pi-\theta) \tag{5}$$

$$\sigma_{np} = \alpha^3(\theta)+4\alpha^2(\theta)\,\alpha(\pi-\theta)+4\alpha(\theta)\,\alpha^2(\pi-\theta) \tag{6}$$

$$\sigma_{p\bar{p}} = \alpha^3(\theta) \tag{7}$$

A comparison of the formulae (5)–(7) with experimental data at primary momenta about 6 GeV/c shown in Fig. 2. A reasonable agreement between the predictions and the data is found. The function $\alpha(\theta)$, which was used for the calculation of the curves presented in Fig. 2, is plotted in Fig. 3.

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