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POMERANCHUK EXCHANGE AND MULTI-PION PRODUCTION

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A B S T R A C T

A simple test for Pomeranchuk exchange dominance in multi-pion production is obtained from isospin relations and used to show that present production data are not compatible with this assumption.

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Many salient aspects of multi-pion production in high energy interactions have been quite successfully described by dynamical models based on multi-Regge exchange (MRM) ¹⁾. However, the role of the Pomeron exchange ($\mathbb{P}$: $I^G = 0^+$, $J^P = 0^+$) in these models is presently not very well understood: the available phase space is through energy-momentum conservation restricted by the relation ²⁾

$$\prod_{i=2}^{N-1} \left[(\sqrt{-t_{i-1}} + \sqrt{-t_i})^2 + m_i^2 \right] \geq \frac{1}{S} \prod_{i=1}^{N-1} s_i \quad (1)$$

where

$$s_i = (p_i + p_{i+1})^2; \quad t_i = (p_A - \sum_{k=1}^i p_k)^2; \quad i = 1, \dots, N-1$$

$$S = (\sum_{i=1}^N p_i)^2; \quad p_i^2 = m_i^2, \quad i = 1, \dots, N$$

(with p_A denoting the four-momentum of one of the incident particles). The sharp t_1 damping, provided by the MRM matrix element, thus tends to suppress large sub-energies s_1 at fixed total s , and for lower s_1 $\mathbb{P}$ exchange (if otherwise allowed) is less likely to dominate the appropriate two-body reaction. For this reason a clear empirical way to test if, and at what energies, $\mathbb{P}$ exchange becomes dominant in multi-particle production is of considerable interest.

The aim of this note is to point out that such a test is in fact provided by simple isospin relations between different charge configurations, with given initial state. In view of (1) we expect at a given energy three-body final states to be the most likely $\mathbb{P}$ dominated channels. Consider the reactions

$$\pi^+ P \rightarrow \pi^+ \pi^0 P \quad (2a)$$

$$\pi^+ \pi^+ N; \quad (2b)$$

the corresponding $\mathbb{P}$ exchange diagrams are shown in Figs. 1a and 1b.

Now, in general, the $P\pi^0$ and $N\pi^+$ subsystems in (2a) and (2b), respectively, can be present both in isospin $I=\frac{1}{2}$ and $I=\frac{3}{2}$ states; if, however, $\overline{TP}$ exchange dominates, then only the $I=\frac{1}{2}$ state can occur and hence the predicted cross-section branching ratio for (2a)/(2b) is $\frac{1}{2}$.

By the same argument $\overline{TP}$ dominance yields for the reactions (cf., Figs. 1c and 1d)

$$PP \rightarrow PP\pi^0 \quad (3a)$$

$$PN\pi^+ \quad (3b)$$

again a predicted branching ratio of $\frac{1}{2}$.

On the other hand, experimentally quite well satisfied predictions of charge configuration branching ratios for many-body production cross-sections have been obtained ³⁾ by simply projecting the full final state isospin onto that of the initial state, assuming cancellation of interference terms ("isospin projection"). This implies for reactions (2a), (2b) and (3a), (3b) that the $I=\frac{1}{2}$ and $I=\frac{3}{2}$ states of the pion-nucleon subsystems contribute equally; the predicted branching ratios then are $\frac{2}{3}$ and $\frac{1}{3}$ for (2a)/(2b) and (3a)/(3b), respectively.

In Figs. 2 and 3 we show the measured ⁴⁾ cross-sections of reactions (2a) and (3a) together with their predictions obtained, respectively, from (2b) and (3b) by $\overline{TP}$ exchange dominance as well as by isospin projection. It is seen that while the latter prediction (assuming equal isospin $\frac{1}{2}$ and $\frac{3}{2}$ subsystem contributions) is rather well satisfied above ^{*}) $P_{lab} \sim 3-4$ GeV/c, the $\overline{TP}$ dominance (admitting isospin $\frac{1}{2}$ only) is clearly excluded up to the highest data points.

^{*}) Deviations below that energy are presumably due to predominant N_{1236}^* and/or ϱ formation.

For π^-P three-body processes the two predictions are not distinct enough to allow with present experimental errors a clear check. Multi-Pomeranchuk dominance in reactions with higher particle numbers is, as expected from (1), excluded even more strongly: thus e.g., for $\sigma(\pi^-P \rightarrow P \pi^+ 2 \pi^- \pi^0) / \sigma(\pi^-P \rightarrow N 2 \pi^+ 2 \pi^-)$ $\overline{P}$ exchange dominance would predict the value 0.5, while in fact the isospin projection value of 1.69 is well satisfied ⁵⁾ at least up to $P_{lab} \sim 16$ GeV/c.

We thus find that the present multi-pion cross-sections are not (yet) compatible with the assumption of $\overline{P}$ exchange dominance.

It should be noted, however, that this result does not exclude the dominance of contributions with "elastic" scattering for a subsystem over those with "inelastic" subsystem reactions: thus, for (3b), the contribution of Fig. 4b may with increasing energy certainly be negligible compared to 4a; our result merely indicates that $I=1$ exchange contributions to elastic scattering must be taken into account ⁶⁾ for the MRM at present energies.

For this reason a test for $\overline{P}$ dominance in production reactions should concentrate on isospin relations; from Dalitz plot distributions generally only information regarding the relative role of contributions as in Figs. 4a, 4b, can be obtained.

Since the subenergies s_i admitted at present lab. momenta by relation (1) are still quite low, further tests of the $\overline{P}$ dominance relations at higher energies (or fixed subenergies of the non- $\overline{P}$ exchange subsystem) would be of great interest.

R E F E R E N C E S

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- 6) Cf., e.g., J.G. Rushbrooke et al., Contribution Nr. 560 to Vienna (1968) (loc.cit. 1), for a non-reggeized elastic ansatz.

FIGURE CAPTIONS

Figure 1 :

Cf., text.

Figure 2 :

Measured values of $\sigma(\pi^+P \rightarrow \pi^+ \pi^0 P)$ (●) compared with predictions from $\sigma(\pi^+P \rightarrow \pi^+ \pi^+ N)$ via Pomernanchuk dominance (■) and via isospin projection (▲).

Figure 3 :

Measured values of $\sigma(PP \rightarrow PP \pi^0)$ (●) compared with predictions from $\sigma(PP \rightarrow PP \pi^+)$ via Pomernanchuk dominance (■) and via isospin projection (▲).

Figure 4 :

Cf., text.

(a)

(b)

(c)

(d)

FIG.1.

FIG.2

FIG. 3

(a)

(b)

FIG. 4