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ON CHARGE EXCHANGE AND SCATTERING IN REACTIONS ACCOMPANIED BY PION PRODUCTION AT HIGH ENERGIES

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Let us consider the interactions between fast particles and nucleons accompanied by the production of a π – meson. Some of these interactions are likely to be due to the scattering of an incident particle on any virtual meson[1] of the nucleon pion cloud, as a result of scattering the above π – meson is being 'knocked out'. For definitness we assume at first that the nucleon dissociation follows the scheme $N \to N\pi$, i.e., after the π – meson had been knocked out, the target nucleon remains a nucleon. This approach enables us to make use of the ideas developed in /2–4/ in which the processes of elastic scattering and charge exchange scattering at large energies of the colliding particles have been treated. In particular, there were some indications that at high energies the interaction is independent of the isotopic states of particles participating in the reaction.

By analogy with the results of /2–4/ one can conclude that the scattering of the incident particle on a virtual π -meson will be likely to be accounted for by the elastic (diffractional) scattering[2] i.e., the cross sections for the scattering with the charge exchange will be small. This will lead to the appearance of the processes with a distinctive fast particle which has the same nature and sign as an incident particle, and to the corresponding relations between the cross sections for such reactions. Since the cross section for the diffractional scattering is weakly dependent upon energy and does not tend to zero with an increase of energy, then the cross section for the production of one π – meson will also remain finite at high energies.

From this standpoint consider the reactions of $\pi^{\pm,0}$ mesons with protons accompanied by the production of one additional π – meson. For the cases with a distinctive fast particle (in the given case it is a $\pi^{\pm,0}$ meson) we obtain, for instance, the following relations for the cross sections:

$$\sigma(\pi^- p \to \pi^0 \pi^0 n) = \sigma(\pi^0 p \to \pi^+ \pi^- p) = 0. \qquad (1)$$

The vanishing of $\sigma(\pi^- p \to \pi^0\pi^0 n)$ and $\sigma(\pi^0 p \to \pi^+\pi^- p)$ takes place because in our consideration these processes are analogous to the reactions of scattering with a charge exchange, the cross sections for which at high energies are likely to tend to zero. /2–4/

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[1] The results of /1/ may serve as a certain confirmation of such a treatment.

[2] It is assumed that in $\pi\pi$ interactions at high energies (by analogy with πN interactions) the inelastic processes which give rise to the diffractional π-π scattering play an important role.

As the ratio of the probabilities of the proton dissociation into $\pi^0 p$ and $\pi^+ n$ is ½, the following equalities are obvious

$$\sigma(\pi^+ p \to \pi^+ \pi^0 p) = \sigma(\pi^- p \to \pi^- \pi^0 p) = \sigma(\pi^0 p \to \pi^0 \pi^0 p) =$$
$$= \tfrac{1}{2}\,\sigma(\pi^+ p \to \pi^+ \pi^+ n) = \tfrac{1}{2}(\pi^- p \to \pi^- \pi^+ n) = \tfrac{1}{2}(\pi^0 p \to \pi^0 \pi^+ n) \qquad (2)$$

corresponding to the cases of elastic scattering /2–4/.

The reactions of π – meson production in nucleon interaction with protons may be considered in an analogous way. For the reactions with a distinctive fast nucleon, we shall have, e.g.

$$\sigma(np \to p\pi^- p) = 0, \qquad (1')$$

$$\sigma(pp \to p\pi^0 p) = \sigma(np \to n\pi^0 p) =$$
$$= \tfrac{1}{2}\,\sigma(pp \to p\pi^+ n) = \tfrac{1}{2}\,\sigma(np \to n\pi^+ n). \qquad (2')$$ 3/

Another feature of the processes discussed above will be the presence of a slow nucleon (the product of the target proton dissociation), which as a result of scattering receives the energy of the order of the binding energy of the virtual π – meson.

Thus, to check experimentally the above assumptions and the corresponding relations it is necessary to select the events with a fast particle, which is identical to an incident one, and with a slow nucleon.

If in the process of dissociation the proton is considered to pass into the excited state (the isobar with an isotopic spin T = 3/2), then it is possible to obtain similar relations for the reactions accompanied by the production of two π – mesons (the second π – meson is produced as a result of the isobar decay). As well as in the case of proton dissociation into a nucleon and a π – meson, the relations will not, evidently, depend upon the kind of the incident particle.

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3/ All the above relations may be also obtained by using the most general expressions for the amplitudes of the reactions. At the same time it is necessary to assume the amplitudes of the reactions, in which the charge exchange of an incident particle occurs, to be equal to zero. In the case of the reactions πp it is sufficient to turn into zero four such amplitudes, and in the case of Np reactions – two of them. This leads to the vanishing of the remaining amplitudes of the reactions with the charge exchange and to relations (1), (2), (1′), (2′). It should be, however, emphasized, that the assumption about the vanishing of the cross sections for the charge exchange reactions may be justified only in the framework of some suitable model (e.g. the model treated in this note).

Consider, for instance, the reactions of charged π – mesons with protons . For the cross sections for possible processes, we get

$$\sigma(\pi^- p \to \pi^0 \pi^0 \pi^0 n) = 0, \qquad (1'')$$

$$\begin{aligned} \tfrac{2}{5}\sigma(\pi^- p \to \pi^- \pi^+ \pi^- p) &= \tfrac{2}{5}\sigma(\pi^+ p \to \pi^+ \pi^+ \pi^- p) = \\ = \sigma(\pi^- p \to \pi^- \pi^+ \pi^0 n) &= \sigma(\pi^+ p \to \pi^+ \pi^+ \pi^0 n) = \\ = \sigma(\pi^- p \to \pi^- \pi^0 \pi^0 p) &= \sigma(\pi^+ p \to \pi^+ \pi^0 \pi^0 p). \end{aligned} \qquad (2'')$$

Equalities (1″) and (2″) are analogous to (1) and (2), respectively. An additional feature of these reactions consists in the presence of pairs of slow particles[4/] which are created as a result of the isobar decay. So, for the reaction $\pi^- p \to \pi^- \pi^+ \pi^- p$ ($\pi^+ p \to \pi^+ \pi^+ \pi^- p$) i.e., in 5/9 cases with a distinctive fast particle, there must be observed pairs of slow charged particles, provided the ratio of the frequency of the pair production $p\pi^+$ to that of the pair production $p\pi^-$ must be 9. Analogous relations for the reactions of any particles with protons can be easily derived by using the equalities obtained.

In conclusion I wish to express my gratitude to M.I. Podgoretsky who drew my attention to the problem treated above and made some essential remarks in the course of the work, as well as to I.M. Gramenitsky for stimulating discussions.

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4/ Instead of a slow nucleon in case of the proton dissociation into $N\pi$.