

On the Mechanism of Reactions of Diffractive Pion Production by Protons with an Energy of 20 GeV

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Abstract

Full Text

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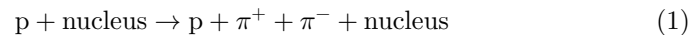
Physics

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On the Mechanism of Reactions of Diffractive Pion Production by Protons with an Energy of 20 GeV

In recent years a special type of inelastic interaction of high-energy particles with nuclei has been studied (coherent interactions), in which the target nucleus participates in the reaction as a whole, receiving only a small momentum and remaining in its ground state (or undergoing a small collective excitation). Reactions involving protons have been discovered only recently (¹⁻⁴) and have not been sufficiently investigated.

In the present work we study reactions of diffractive dissociation



of protons with momentum 20.8 GeV/c on nuclei of a nuclear emulsion exposed in a strong ($H = 180$ kOe) magnetic field.

From the interactions found over an effective length of 2.32 km of scanned track, 404 stars with 3 and 4 charged particles satisfying the necessary selection criteria for NN interactions were selected. Measurements of the kinematic characteristics and particle identification were carried out for the overwhelming majority of secondary tracks. The accuracy of the momentum measurements was $\sim 10-15\%$.

Fig. 1. Distributions of q_{\parallel} and q_{\perp} for events of the 1st (a) and 2nd (b) groups.

To isolate reactions (1), 62 stars were selected with p-, π^+ - and π^- -particles in the final state (of these, in 47 events (group 1) there were no indications of nuclear excitation) and 27 stars of the type $pp\pi^+\pi^-$ (clean quartets), the total energy of the secondary particles in which was, within the errors, equal to the

Fig. 2 and Fig. 3

Figure 2: Fig. 2 and Fig. 3

energy of the primary particle. Reactions (1) should be present among the events of group 1; the remaining events (group 2) will be regarded as background.*

Reactions (1) should be characterized, as is known, by the smallness of the momentum transferred to the nucleus. Figure 1 shows the distributions of the missing longitudinal ($q_{\parallel} - T$) and transverse (q_{\perp}) momenta in the selected cases:

$$q_{\parallel} - T \cong \sum_i (m_i^2 + p_{\perp i}^2) / 2p_i - m_0^2 / 2p_0, \quad (2)$$

$$q_{\perp} = \left[\left(\sum_i p_{\perp i} \cos \varphi_i \right)^2 + \left(\sum_i p_{\perp i} \sin \varphi_i \right)^2 \right]^{1/2}, \quad (3)$$

* The assumption of the identity of the characteristics of the ($p\pi^+\pi^-$)-system from the reactions $pp \rightarrow pp\pi^+\pi^-$ and $pn \rightarrow pn\pi^+\pi^-$ is by no means indisputable; however, it is justified a posteriori: all the characteristics considered below of these systems from the “dirty” triplets and quartets coincide within the errors, differing substantially from those in group 1.

where $p_i, p_{\perp i}, m_i, \varphi_i$ ($i = 1, 2, 3$) are the momentum, transverse momentum, mass, and azimuthal angle of the i -th secondary particle; p_0, m_0 are the corresponding characteristics of the incident proton; and $T \ll q$ is the kinetic energy of the recoil nucleus.* Unlike the background events, the majority of events of group 1 are concentrated in the region of very small transferred momenta. Assuming that reactions (1) are present among them, it is easy to estimate their cross section. For given upper limits

Fig. 2

Fig. 3

Fig. 2. Distributions of $M_{p\pi^+}^*$ (solid line) and $M_{p\pi^-}^*$ (dashed line) in reactions (1)

Fig. 3. Angular distribution of protons in the rest systems of $p\pi^+$ (solid line) and $p\pi^-$ (dashed line), relative to the primary direction

of q_{\parallel}^{\max} and q_{\perp}^{\max} , the longitudinal and transverse momenta transferred to the nucleus in an inelastic diffraction process, the number N of reactions (1) is

$$N = n_1 - n_2(N_1 - n_1) / (N_2 - n_2), \quad (4)$$

where N_k ($k = 1, 2$) is the total number of events in the k -th group, and n_k is the number of events of the k -th group in the region $q_{\parallel} < q_{\parallel}^{\max}$, $q_{\perp} < q_{\perp}^{\max}$. Theory gives only estimates of q_{\parallel}^{\max} and q_{\perp}^{\max} ; on the other hand, the difference between the groups (Fig. 1) is so large that varying q_{\parallel}^{\max} and q_{\perp}^{\max} within fairly wide limits ($q_{\parallel}^{\max} > 0.08$, $0.25 < q_{\perp}^{\max} < 0.5$ GeV/ c) leads only to insignificant changes in N . For the choice $q_{\parallel}^{\max} = 0.1$, $q_{\perp}^{\max} = 0.4$ GeV/ c , $N = 36.9 \pm 6.7$; the mean free path for events of type (1) is 63_{-10}^{+14} m, the average cross section on photoemulsion nuclei is $\sigma = 3.4 \pm 0.6$ mb, and the probable number of incoherent clean triples in this region turns out to be very small ($< 10\%$). With an increase of q_{\parallel}^{\max} and q_{\perp}^{\max} , however, the fraction of the latter grows noticeably; we therefore think that the selection criteria ($q_{\parallel} < 0.15$ GeV/ c , q_{\perp} arbitrary) used in work (4) are not sufficiently stringent.

Figure 2 presents the distributions of the effective masses of the $p\pi^+$ and $p\pi^-$ systems in 38 clean triples with $q_{\parallel} < 0.1$, $q_{\perp} < 0.4$ GeV/ c . Most of the values of $M_{p\pi^+}^*$ are concentrated in the mass region of the $\Delta^{++}(1236)$ isobar. To test the assumption of dominant formation of this isobar in reactions (1), Fig. 3 shows the corresponding decay angular distributions.

* We note in passing that the known relation between q_{\parallel} , q_{\perp} , M , and M^* (M and M^* are, respectively, the masses of the nucleus and of the $(p\pi^+\pi^-)$ -system), which follows from the kinematics of reactions (1) and is usually used (3, 4) to calculate q_{\parallel} , in addition to some arbitrariness associated with lack of knowledge of M , has a larger error than formula (2).

For the $(p\pi^+)$ system there is good agreement with the distribution expected in the case of Δ^{++} production, of the form $1 + 3 \cos^2 \theta$, whereas in the $(p\pi^-)$ system the angular distributions are asymmetric. The distribution of M^* (not shown) does not contradict that expected from phase-space theory ⁽⁶⁾; however, the question of the possible production of cascade-decaying heavy isobars remains open because of insufficient statistics.

Figure 4 shows the distribution in the square of the four-momentum transferred to the nucleus, $t' = t - t_{\min}$ (t_{\min} is the minimum value of t for the given M^*). It agrees with the distribution $d\sigma/dt' \sim \exp[-\beta|t'|]$ for $\beta = 28_{-12}^{+15}$. Taking into account the experimental data on the scattering of protons by nuclei (for example, ⁽⁷⁾), we arrive at the probable conclusion that the light nuclei of the emulsion participate predominantly in reactions (1) at this energy.

Fig. 4. Distribution in the square of the four-momentum transferred to the nucleus. The straight line corresponds to

$$d\sigma/dt' \sim \exp[-28|t'|].$$

In conclusion, we note the considerable similarity in the dynamics of pion ($\pi \rightarrow 3\pi$) and proton ($p \rightarrow p2\pi$) dissociation in the field of nuclei at energies ~ 20

GeV: equality of cross sections, formation of resonances (respectively, the ρ -meson and Δ^{++} -isobar) in the system of two of the three particles, etc., which apparently points to a common mechanism for these reactions.

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