INVESTIGATION OF DIFFRACTION PRODUCTION OF π MESONS BY PROTONS WITH AN ENERGY OF 20 GeV

PHYSICS

1966

SovietRxiv

Abstract

Full Text

UDC 539.12+539.107.37

PHYSICS

E. G. BOOS, Academician of the Academy of Sciences of the Kazakh SSR Zh. S. TAKIBAEV, R. A. TURSUNOV

INVESTIGATION OF DIFFRACTION PRODUCTION OF π MESONS BY PROTONS WITH AN ENERGY OF 20 GeV

The possibility of diffraction dissociation was first pointed out in the work of Feinberg and Pomeranchuk ([1]). By the present time, extensive experimental material has been obtained on the diffraction dissociation of π mesons in the field of a nucleus, belonging to the region of accelerator energies ([2–4]).

In our report, presented at the XVI meeting of the Emulsion Committee of the Joint Institute for Nuclear Research ([5]), a preliminary estimate was obtained for the mean free path for diffraction production of π mesons by protons with an energy of 20 GeV in emulsion nuclei, amounting to (79±25) m. The present work is devoted to a further study of the processes of coherent production of pions in three-prong events formed in Ilford G-5 emulsion by protons with momentum 19.8 GeV/c.

In contrast to diffraction dissociation of π mesons, in similar events formed by protons it is necessary to know the nature of the secondary particles, since the usually used angular criterion for selecting the events of interest to us takes in this case the form

$$\delta = (\sin\theta_1 + \sin\theta_2) + \frac{M}{\mu}\sin\theta_s < A^{-1/3} + \frac{M^2}{2P_0\mu},$$

where θ_1, θ_2 are the emission angles of pions relative to the direction of motion of the primary proton in the laboratory coordinate system; θ_3 is the emission angle of the proton in the laboratory coordinate system; M and μ are, respectively, the masses of the proton and the π meson; A is the atomic number of the nucleus on which coherent dissociation occurs; P_0 is the momentum of the primary proton.

Therefore, in order to select coherent events, an identification of secondary particles was carried out in 179 three-prong interactions found over a total length of 2927 m and satisfying the usual criteria for nucleon–nucleon collisions ([6]). The identification was performed by measuring ionization losses and multiple Coulomb scattering on secondary tracks ([7]). For further analysis, events were

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

selected in which recoil nucleons and β electrons were absent and which, according to the identification, did not contradict events of the coherent type. To the 107 events selected in this way, the angular criterion was applied, with the value $A^{-1/3}$ chosen equal to 0.44.

Figure 1 presents the distribution of the selected events with respect to the quantity δ, and the dashed line shows the distribution of 50 background events. The background includes three-prong events with a recoil nucleon, a β electron, and a recoil nucleus, as well as four-prong interactions of the type $1 + 3p$.

The normalization of both distributions was carried out over the region of values $\delta > 0.6$, since at a proton momentum of 19.8 GeV/c the limiting value of δ for isolating coherent events is equal to 0.6. From comparison of the distributions it is seen that in the region of small values of δ there is an excess over the background, going beyond the limits of statistical errors, which can be explained by the manifestation of the mechanism of diffraction dissociation. The region of values $\delta < 0.6$ contains 46 events; after subtraction of the background this amounts to

is 22 events,* which corresponds to a mean free path for coherent interaction of protons of (133 ± 56) m, or to an effective cross section $\sigma = (1.6 \pm 0.7)$ mb. The value found is, naturally, closer to the true one than the previously obtained value ([5]), since particle identification is taken into account here.

Fig. 1. Distribution of the selected events with respect to the value δ

To clarify the dynamics of the coherent process, an energy requirement, usually used to separate diffraction-dissociation events,

$$\sum_{i=1}^{3} E_i \geq 0.75 E_0,$$

was applied to 46 events having $\delta < 0.6$. The 30 cases remaining after this procedure can be divided into 2 groups: 13 events in which reliable identification of secondary particles was carried out, and 17 events with doubtful identification of individual tracks.

Fig. 2. Distribution with respect to the square of the four-momentum q^2 transferred to the target nucleus

Fig. 3

Figure 3: Fig. 3

Fig. 4. Distribution in the magnitude of the effective mass of the system of three particles

Figure 4: Fig. 4. Distribution in the magnitude of the effective mass of the system of three particles

Fig. 3. Distribution with respect to the transverse momentum $P_\perp$ carried away by the system $(p\pi\pi)$

Figure 2 shows the distribution of the selected events with respect to the square of the four-momentum q^2 transferred to the target nucleus. This distribution, like the subsequent ones, is normalized to 30 events, with the shaded part corresponding to 13 interactions.

The distribution has a sharp peak in the region $q^2 < 0.1$ $(\text{GeV}/c)^2$, which indicates a substantial role of an almost elastic process of scattering on the nucleus. The mean value of q^2 is 0.14 ± 0.03 $(\text{GeV}/c)^2$** for all events (0.15 ± 0.04 $(\text{GeV}/c)^2$ for 13 events).

* It is appropriate to note here that attempts to determine the number of diffraction events by selecting according to threshold values of the transferred four-momentum or the transverse momentum of the system $(p\pi\pi)$ give values that agree well with the value given above.

** In finding this value, as well as the corresponding values from the subsequent distributions, the cases 41 and 173, which lie far outside the shaded region, were not taken into account.

Figure 3 shows the distribution in the magnitude of the transverse momentum $P_\perp$ carried away by the system $(p\pi\pi)$. The distribution is collimated in the region of small values of $P_\perp$: the fraction of events with $P_\perp < 0.3$ GeV/c is 77%. The mean value of the transverse momentum is 0.18 ± 0.03 GeV/c (0.17 ± 0.05 GeV/c), which is considerably smaller than the value of the mean transverse momentum from three-prong pn interactions (0.30 ± 0.03) GeV/c ([8]).

It is known that at accelerator energies, with increasing mass of the particle,

Fig. 4. Distribution in the magnitude of the effective mass of the system of three particles

there is an increase in the magnitude of the transverse momentum ([9]). The mean value of the transverse momentum obtained by us is noticeably smaller than the values given in work ([9]), which once again confirms the difference in the interaction mechanism.

The distribution in effective masses $\mathfrak{M}$ of the system of three particles is shown

in Fig. 4. More than 70% of the events fall in the interval 1.3–1.7. The mean value is $\mathfrak{M} = (1.61 \pm 0.30)$ GeV for all events ((1.63 ± 0.45) GeV for 13 events). The statistical accuracy of the data obtained does not make it possible to draw an unambiguous conclusion concerning the resonant character of the production of π-mesons. However, the possibility is not excluded that events of the coherent type are formed through nucleon isobars with masses 1.512 or 1.688 GeV. Further calculations will make it possible to check the reliability of this assumption.

In conclusion, the authors express their gratitude to O. V. Guchenkova, K. G. Zaitsev, T. I. Mukhordova, and A. V. Kholmetskaya, who took part in the measurements and processing of the data, and also to A. Kh. Vinitskii for taking part in the discussion of the results obtained.

Institute of Nuclear Physics
Academy of Sciences of the Kazakh SSR

Received
24 VI 1966

CITED LITERATURE

1. E. L. Feinberg, I. Ya. Pomeranchuk, *Nuovo Cim.*, Suppl., **3**, 652 (1956).
2. A. Caforio, D. Ferraro et al., *Nuovo Cim.*, **32**, 1471 (1964).
3. G. Bozoki, E. Fenyves et al., *Phys. Lett.*, **18**, 206 (1965).
4. G. Vegni, H. Winzeler et al., *Phys. Lett.*, **19**, 526 (1965).
5. E. G. Boos, N. P. Pavlova, R. A. Tursunov, Preprint of the Joint Institute for Nuclear Research, P-2623, Dubna, 1966.
6. E. G. Boos, N. P. Pavlova, Zh. S. Takibaev, T. Temiraliev, R. A. Tursunov, *JETP*, **47**, 2041 (1964).
7. E. G. Boos, N. P. Pavlova, Zh. S. Takibaev, R. A. Tursunov, *Instruments and Experimental Techniques*, No. 2, 63 (1965).
8. E. G. Boos, K. G. Zaitsev, N. P. Pavlova, G. Ya. Ruskina, Zh. S. Takibaev, T. Temiraliev, R. A. Tursunov, Preprint of the Joint Institute for Nuclear Research, R-1734, 12, Dubna, 1964.
9. A. DeMarco-Trabucco, L. Montanet, S. Nilsson, *Nucl. Phys.*, **60**, 209 (1964).

Note: Figure translations are in progress. See original paper for figures.