CHARACTERISTICS OF COHERENT INTERACTIONS OF π^- MESONS WITH EMULSION NUCLEI AT AN ENERGY OF 60 GeV

PHYSICS

1970

SovietRxiv

Abstract

Full Text

UDC 539.12

PHYSICS

A. Kh. Vinitskii, V. G. Voinov, I. S. Streltsov,
Academician of the Academy of Sciences of the Kazakh SSR Zh. S. Takibaev,
I. Ya. Chasnikov

CHARACTERISTICS OF COHERENT INTERACTIONS OF π^- MESONS WITH EMULSION NUCLEI AT AN ENERGY OF 60 GeV

In the interaction of high-energy hadrons with nuclei of matter, processes of coherent particle production are observed. With the start-up of the Serpukhov accelerator, it became possible to study these processes up to energies of 60–70 GeV. In [1], the cross section of coherent interactions at an energy of 60 GeV was estimated from an analysis of the emission angles of the particles and of the multiplicity distribution. However, for a more correct selection of such events it is necessary to measure all kinematic characteristics [2].

Fig. 1
Fig. 1

Fig. 2
Fig. 2

In the present work, 3- and 5-prong events in BR-2 type nuclear photoemulsion are studied; these events were found by scanning along the tracks of primary pions over a length of 870 m.

By measuring multiple scattering, the momenta of practically all secondary particles in the 3-prong interactions were determined, as well as in those 5-prong interactions for which $\sum \sin\theta_i \leq 0.3$ (θ_i is the space angle of emission of the secondary particles). The scattering was measured on a semiautomatic MIRE-2 microscope. Spurious scattering due to distortion was excluded by the method of correlation moments [3]. The method for determining momenta was checked on tracks of primary particles. Figure 1 gives the momentum distribution of 54 such particles having a length of not less than 5 cm. The mean momentum value agrees with the energy of the incident pion.

To select coherent events proceeding by the reaction

$$\pi^- + A \to \pi^- + \pi^+ + \pi^- + A^-, \tag{1}$$

Fig. 3

Figure 1: Fig. 3

interactions without gray or black tracks, recoil nuclei, or δ-electron tracks were selected, satisfying the conditions

$$\sum \sin\theta_i \leq 0.3, \qquad \sum (E_i + \Delta E_i) \geq E_0,$$

where E_i and E_0 are the energies of the secondary and primary particles, respectively. Figure 2 gives the distribution in the square of the four-momentum, transferred to the system of three π-mesons in such events. It is seen from the figure that the character of the distribution changes sharply at $\Delta^2 \leq 0.12$ (GeV/c)^2. A similar distribution in Δ^2 for 3-prong interactions was obtained in works ([2,4]), carried out by means of the bubble-chamber technique at an energy of 16 GeV and in nuclear emulsion at an energy of 17 GeV, where it was shown that the peak in the distribution is explained by coherent events. On this basis, for separating coherent interactions, an additional criterion $\Delta^2 \leq 0.12$ (GeV/c)^2 was used. The number of coherent events proceeding via reaction (1), if this criterion is applied, decreases from 50 to 35 m, and accordingly the mean free path increases to $24.8^{+5.0}_{-3.5}$ m at an energy of 17 GeV; the corresponding value is $\lambda = 86^{+25}_{-16}$ m ([2]). On the other hand, the excess of the number of 3-prong events with $\sum \sin\theta_i \leq 0.3$ over the number of background events (4-prong interactions with a gray and black track and 3-prong interactions with a δ-electron) is 50. The same number is given by the excess of 3-prong interactions in the multiplicity distribution ([1]). This discrepancy (15 cases) is probably explained by coherent events of the type

Fig. 3. Distributions in effective masses of the system of three π-mesons: solid line—experiment; dashed line—simulated events; 1 and 2—background curves for carbon and silver nuclei, respectively

$$\pi^- + A \to \pi^+ + 2\pi^- + 2\pi^0 + A'. \tag{2}$$

The mean free path of such a process is $\lambda = 58^{+20}_{-12}$ m. According to the criteria given above, among the 5-prong events 10 coherent interactions proceeding via the reaction

$$\pi^- + A \to 3\pi^- + 2\pi^+ + A', \tag{3}$$

were selected, for which $\lambda = 87^{+40}_{-21}$ m. It follows from this that the cross section of reaction (2) is somewhat larger than or equal to the cross section of reaction (3), and the mean free path for all 5-particle coherent interactions is $\lambda = 34.8^{+8.7}_{-5.8}$ m.

For coherent processes of type (1), the distribution in the effective masses of three π-mesons was constructed (Fig. 3). It is seen from the figure that the distribution has a maximum in the region of 1.1 GeV, which agrees with data obtained at an energy of 17 GeV ([2,4,5]). The observed mass distribution is not explained by the background curve calculated from the pole diagram with ρ-meson exchange and with allowance for the nuclear form factor ([7]). According to ([5]), the nuclear form factor was taken into account by the multiplier $\exp\left[-\frac{R^2}{3}\Delta^2\right]$ in the expression for the cross section of inelastic interaction of a π-meson on a nucleon with the production of two particles. In Fig. 3 the curves calculated for carbon and silver nuclei are shown; they differ only slightly from one another and have a maximum in the region 2.4–3.0 GeV. The maximum in the distribution at 1.1 GeV may be caused either by the Deck effect ([6]), or by the fact that the production cross section of the A_1-meson in 3-particle reactions does not decrease with increasing energy of the incident π-meson. On the other hand, the background constructed from events simulated by the Monte Carlo method, with the use of the same selection criteria as for real interactions, also has a maximum at 1.1 GeV (Fig. 3).

In 5-prong coherent interactions, the effective masses of 5 particles lie in the region 1.2–2.6 GeV, with a mean value of 2.02 GeV.

Taking into account the above, the following conclusions may be drawn: a) the cross section for coherent production of the $\pi^+\pi^-\pi^-$ system in the final state increases with increasing energy of the primary particle, while the maximum in the distribution over effective masses of this system remains in the same region as at an energy of 17 GeV; b) the number of 5-particle coherent interactions increases substantially. Thus, at 17 GeV [(8)] the fraction of events of reaction (3) relative to reaction (1) is 2%, whereas at an energy of 60 GeV the fraction of 5-particle coherent states relative to 3-particle states is 70%. The latter value may be somewhat overestimated, since the reaction $\pi^- A \to \pi^-\pi^0\pi^- A'$ has not been taken into account.

Institute of Nuclear Physics
Academy of Sciences of the Kazakh SSR
Alma-Ata

Received
12 II 1970

REFERENCES

[1] Z. A. Anzon, A. Kh. Vinitskii et al., *Yadern. fiz.*, **10**, 5, 991 (1969).
[2] A. Kh. Vinitskii, I. S. Streltsov et al., *Izv. AN KazSSR, ser. fiz.-matem.*, **2**, 90 (1967).
[3] V. G. Voinov, I. Ya. Chasnikov, *Multiple Scattering of Particles in Nuclear Photoemulsions*, Alma-Ata, 1969.
[4] J. F. Allard, D. Drijard et al., *Nuovo Cim.*, **46A**, 731 (1966).
[5] J. J. Veillet, *Sci. Rep. CERN*, **7/1**, 537 (1968).

[6] R. T. Deck, *Phys. Rev. Lett.*, **13**, 5, 169 (1964).
[7] A. Kh. Vinitskii, I. G. Golyak et al., *JETP*, **44**, 2, 424 (1963).
[8] R. Huson, H. J. Lubatti et al., *Phys. Lett.*, **B28**, 3, 208 (1968).

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