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MULTIPLE CHARGED PARTICLE PRODUCTION IN $\pi^- p$ AND $\pi^- n$ INTERACTIONS AT p = 40 GEV/C

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MULTIPLE CHARGED PARTICLE PRODUCTION IN π^-p AND π^-n INTERACTIONS AT $p = 40$ GEV/C

Направлено в ЯФ

1. Introduction

In recent papers, in theoretical explanations of high-energy strong interaction processes, a tendency has appeared to consider hadrons as a composite system with internal degrees of freedom. In this connection, we should indicate the droplet model [1], the parton model [2] and the coherent state model [3].

In the coherent state model it is suggested that the hadron states in strong interaction processes at high energies correspond to the coherent states of a complex system the excitation spectrum of which is described, in the simplest case, by the four-dimensional relativistic oscillator. It is remarkable that the coherent state model predictions are in qualitative agreement with the calculations performed in the framework of the quantum field theory model, using the approximations which realize the straight-line path conception [4].

The coherent nature of the hadron interactions is also shown in recent papers on the strong coupling theory [5] and dynamic composite model [6].

The approach, based on the coherent state model and the straight-line path conception, has been applied to the study of the general regularities of multiple particle production at high energies[3,4,7,8,9].

One of the main results of this approach is the prediction of the automodel character of the asymptotic behaviour of strong particle interactions at high energies, which is characterized by definite scale relations between the cross sections for these processes. Of importance are also the following consequences of this approach: linear dependence of the average multiplicity upon the squared momentum transfer in the diffractional dissociation region; generalized Poisson character of the secondary particle distribution which, in the general case, is defined by a superposition of the Poisson functions; possible existence of a simple relation connecting the asymptotic behaviour of the average multiplicity with the total cross section and the slope parameter for the diffractional peak $\langle n \rangle = c_1 \frac{A(s)}{\sigma_{tot}} + c_2$.

Recent experiments at the Serpukhov accelerator have revealed a unique possibility of checking high-energy multiple particle production models. However, to obtain a direct fitting of theoretical constructions to experiment it is necessary to take into account the isotopic structure and the particle charge which are usually disregarded in the qualitative consideration.

In the present paper an attempt is made to consider multiple particle production at high energies using the results and ideas which follow from the coherent state and field theory models in the framework of the straight-line path approximation.

2. Multiple Pion Production Model

At present there is a number of models and empirical approaches (Chew - Pignetti, Wang, Czyzewski - Rybicki, Grishin et al.)[10-13] to the description of charge relations for multiple particle production processes.

The most useful in the analysis of experimental data is the Wang-I model[10]. It is based on the assumption about the statistical independence of charged particle pair production. However, the comparison of this model with the experimental data obtained from the Serpukhov two-meter propane chamber irradiated by 40 GeV π^- mesons[14] shows that in this model the average number of charged meson pairs in $\pi^- p$ and $\pi^- n$ interactions is different which, generally speaking, contradicts the idea about isospin independence.

Now, we consider a picture of multiple particle production in $\pi^- p$ and $\pi^- n$ interactions the mechanism of which is the statistically independent pair production $(\pi^+\pi^-)$[x]. Thus, the distribution over the number of charged particles has the Poisson character. According

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[x] For simplicity, the strange particle production is not considered here.

to the assumption about statistical independence, the average number of these pairs should be independent of the sort of colliding (leading) particles and is thus identical for $\pi^- p$ and $\pi^- n$ collisions.

We also suppose that in the process of collision the leading nucleon can be dissociated into a pion and a nucleon with local charge conservation.

In this picture we are dealing with the following dissociation channels:

1) $N \to N$
2) $N \to N\pi^0$ } with α probability
3) $N \to N'\pi^{\pm}$ with β probability

The condition of probability conservation yields the relation

$$\alpha + \beta = 1 . \tag{1}$$

According to our premises, the multiplicity distribution is for $\pi^- p$ collisions

$$W_{n_\pm}(\pi^- p) = P_{\frac{1}{2}(n_\pm - 2)}(a) \tag{2}$$

for $\pi^- n$ collisions

$$W_{n_\pm}(\pi^- n) = \alpha P_{\frac{1}{2}(n_\pm - 1)}(a) + \beta P_{\frac{1}{2}(n_\pm - 3)}(a), \tag{3}$$

where a is the average number of $\pi^+\pi^-$ pairs and $P_n(A)$ is the Poisson factor $P_n(A) = e^{-A}\frac{A^n}{n!}$.

As it follows from eqs. (2) and (3), the average number of charged particles can be presented in the form

$$\langle n_{\pm} \rangle = \langle \ell_{\pm} \rangle + 2a , \tag{4}$$

where

$$\langle \ell_{\pm} \rangle_{\pi^- p} = 2 , \tag{5}$$

$$\langle \ell_{\pm} \rangle_{\pi^- n} = a + 3\beta = 1 + 2\beta . \tag{6}$$

Here $\ell_{\pm}$ is the number of charged particles among the products of dissociation of colliding particles.
From here

$$\delta n_{\pm} = \langle n_{\pm} \rangle_{\pi^- p} - \langle n_{\pm} \rangle_{\pi^- n} = a - \beta = 1 - 2\beta . \tag{7}$$

On the basis of the formulas derived it is not difficult to calculate the dispersion $(D = \langle n^2 \rangle - \langle n \rangle^2)$

$$D_{\pi^- p} = 4a , \tag{8}$$

$$D_{\pi^- n} = 4a + 4a\beta . \tag{9}$$

The simple picture suggested here may be used for the comparison with experimental data. The subsequent section is just devoted to the comparison of this model with the experimental data from the Serpukhov two-meter propane chamber.

3. Comparison of the Model with Experiments on $\pi^- p$ and $\pi^- n$ collisions at p =40 GeV/c

The experimental results on the distribution of events over the secondary charged particle multiplicity in pc =40 GeV collisions are well described by the Wang-I model[14]. Other models (Wang-II, Poisson, etc.) are completely excluded. The results of fitting of the distribution over multiplicity (Wang-I) are given in Table I.

Table I.

Type of interaction	Number of events	$\bar{n}$	$\sqrt{D}$	χ^2	Degree of freedom
$\pi^- p$	4400	$5.62 \pm .04$	2.75	8	8
$\pi^- n$	1860	$5.32 \pm .07$	2.82	13	7
$\pi^- n$	fit by the suggested model			8.5	7

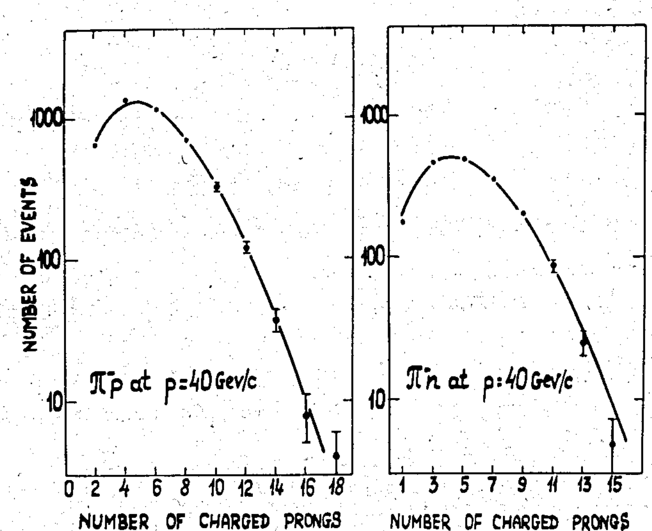
It is seen from the table that the description of the $\pi^- n$ interactions is worse. However, in the Wang-I model $a_{\pi^- p} = \frac{1}{2}(\bar{n}_\pm - 2) = 1.81 \pm 0.02$ and $a_{\pi^- n} = \frac{1}{2}(\bar{n}_\pm - 1) = 2.16 \pm 0.04$, i.e. the average number of pairs is different.

On the basis of the above consideration, the suggested model was used for describing jointly the $\pi^- p$ and $\pi^- n$ interactions. Here the average number of pion pairs is the same for both $\pi^- p$ and $\pi^- n$ interactions and is directly determined from the $\pi^- p$ collisions (4,5). In our case $a = 1.81 \pm 0.02$. The parameters α and β can be determined by fitting the distribution (3) with the $\pi^- n$ collisions at the same energy. The comparison has given the following values:

$$\alpha = 0.64 \pm 0.06$$

$$\beta = 0.36 \pm 0.04.$$

With these values of the parameters α and β eq.(7) gives $\delta n_{\pm}$ =0.28±0.07 which coincides with the experimental one 0.30 ± 0.08. The degree of agreement between theoretical and experimental distributions for the $\pi^- n$ interactions was found to be the same as for the $\pi^- p$ interactions (see Table.I and Fig. I)x/.



Thus, satisfactory agreement between the suggested model and experiment makes possible the following conclusions:

a. $(\pi^+\pi^-)$ meson pairs produced in the $\pi^- p$ and $\pi^- n$ collisions have the same characteristics;

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x/ When fitting all the parameters were considered to be free: the results within the errors have coincided.

b. the nucleon charge exchange probability at pc = =40 GeV was found to be 0.36±0.04;

c. identical distribution over the charged particle multiplicity must be, for example, in the $\pi^+ p$ and $\pi^- p$, pp and $p\bar{p}$ interactions.

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