PRODUCTION OF π^0 MESONS IN K^+p INTERACTIONS AT 8.2 GeV/c

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Experimental results on π^0 production in K^+p interactions at 8.2 GeV/c incident momentum are presented. Average π^0 multiplicities for given prong numbers are evaluated. They are consistent both with the corresponding results for pp interactions at 12 GeV/c (chosen for comparison because they have the same average prong number) and with a model where total multiplicity distributions are calculated from the Czyżewski-Rybicki formula and the charge branching ratios from the statistical model. Some averages over the π^0 momentum distribution are also evaluated. In particular it is found that π^0-s produced in two prong interactions go predominantly forward.

1. Introduction

Growing interest in the charged particle and total multiplicity distributions over the past few years has stimulated detailed investigations of π^0 production. However, due to the difficulty of observing the neutral particles, data on π^0 production are still rather scanty. We present the analysis of the production of π^0 mesons in inclusive and semi-inclusive (fixed numbers of charged particles in the final state) K^+p interactions at 8.2 GeV/c incident momentum. This analysis is based on the detection of gamma quanta coming from π^0 decay and undergoing conversion into electron pairs inside the 2m hydrogen bubble chamber. Since the radiation length in hydrogen is about 15 m, only less then 5 per cent of emitted γ-s can be converted. This practically excludes the possibility of reconstructing individual π^0 events.

The film used for this analysis was obtained by the Brussels-CERN Collaboration during an exposure of the CERN 2m hydrogen bubble chamber to a separated K^+ beam of

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8.2 GeV/c at the CERN proton synchrotron. General information about this exposure can be found in Ref. [1] and about K^+p interactions at 8.2 GeV/c in Ref. [2]. Our preliminary results were presented at the Pavia Conference and are quoted in Ref. [3], where references to similar work on π^0 production in other reactions are also collected. Our study yields the first results of this kind for K^+p interactions.

2. *Experimental procedure*

Because of the very short lifetime of a π^0 meson, the electron pair coming from its decay points to the primary vertex where this meson has been produced. About 36 000 pictures were scanned twice for primary K^+p interactions with at least one pointing electron pair in a fixed fiducial region. The scanning efficiency for associated electron pairs was estimated as 91 per cent and the corresponding correction factor was introduced. We measured the tracks of the incoming kaons and of the associated electron pairs. Out of the 1450 events found 96 per cent passed the geometrical reconstruction program Thresh. Tracks with radius below 3.5 cm (corresponding to electron with kinetic energy below 18 MeV) were not measured. In order to reduce the background from V^0-s and unassociated electron pairs the following acceptance criteria, obtained from an experimental study of the $\gamma - V^0$ ambiguity and of the angular resolution, were used:

1. The angle between the momentum of the pair and the line joining the interaction point with the conversion point had to be less than 4° for pairs, where both tracks were measurable, and below 6° for pairs where only one track was measurable.

2. The effective mass of the pair had to be below 15 MeV.

It was estimated that by this selection the V^0 contamination was reduced from 5 per cent to below 2 per cent. About 13 per cent of the pairs were rejected as not associated with the vertices. The number of photons including the unmeasurable ones, accepted for each multiplicity of charged particles is given in Table I.

In order to reduce the statistical error on the number of pairs associated with 8-prong events, all pairs associated with 8-prong stars and passing our selection have been included. This corresponds to the total sample of 200 000 pictures.

TABLE I

The average multiplicities of π^0 mesons produced in K^+p interactions at 8.2 GeV/c and input information

Type of interaction	Cross-section (mb) Ref. [2]	Accepted number of photons	Average weight	$\langle n_{\pi^0} \rangle$
All	13.72±0.4	1375.7	34.6±0.93	1.05±0.09
2-prong	5.72±0.27	724.3	32.6±1.0	1.25±0.11
4-prong	6.65±0.13	546.3	36.3±1.5	0.90±0.09
6-prong	1.29±0.06	103.0	39.1±4.8	0.95±0.13
8-prong	0.074±0.014	17.6	53.2±10.8	0.72±0.22

The errors given in the Table are statistical only.

About 6000 pictures were scanned for all primary interactions, in order to find, by comparison with the topological cross-sections from Ref. [2] the overall normalization.

For each accepted electron pair we calculated its conversion weight W defined as the reciprocal of the conversion probability P. The latter is related to the cross-section for conversion σ_c and to the potential path of the photon in the chamber l by the formula:

$$P = 1-\exp(-\varrho \cdot \sigma_c \cdot l), \tag{2.1}$$

where ϱ denotes the density of protons in liquid hydrogen. The dependence of the conversion cross-section on photon energy can be found in Ref. [4]. The number of produced π^0 mesons n_{π^0} is related to the number of converted photons n_γ by the formula:

$$n_{\pi^0} = \tfrac{1}{2} \langle W \rangle \cdot n_\gamma, \tag{2.2}$$

where $\langle W \rangle$ denotes the conversion weight averaged over all converted photons. The average conversion weight for all the sample and for each multiplicity of charged particles separately is given in Table I.

It has been assumed that all the observed γ-quanta come from decaying π^0-s. Corrections for γ-quanta originating from Σ^0 and η decays, as well as from π^0 decays with Dalitz pairs were estimated to be negligible and consequently ignored.

3. Characteristics of π^0 production

3.1. The average multiplicities

Using the data on γ production one can derive information concerning the production of π^0 mesons. On the basis of the weighted number of accepted photons and of the topological cross-sections we calculated the average number of π^0 mesons produced in all the inelastic K^+p interactions ($\langle n_{\pi^0} \rangle$), and for given multiplicities of charged particles n ($\langle n_{\pi^0} \rangle_n$). In Fig. 1 our results on $\langle n_{\pi^0} \rangle_n$ are compared with corresponding data for pp scattering at 12 GeV/c from Ref. [5]. This is a particularly good reference experiment for us, since the average multiplicity of negative charged particles is 0.69 ± 0.06 in K^+p interactions at 8.2 GeV/c and 0.71 ± 0.02 in Ref. [5]. It is seen from the figure that at present accuracy the two sets of data are consistent with each other. The average number of π^0 mesons per inelastic interaction in our sample is 1.05 ± 0.09 to be compared with $1.18 \pm \pm 0.09$ for the pp interactions at 12 GeV/c. This confirms the suggestion from Ref. [3] that at given average multiplicity of charged particles there is little difference between π^0 production in different reactions.

The slow decrease of $\langle n_{\pi^0} \rangle_n$ with n, means weak negative correlation between the production of neutral and charged pions. This feature of particle production can be also expressed in terms of Meuller's correlation coefficient

$$f_2^{0-} = \langle n_{\pi^-} \cdot n_{\pi^0} \rangle - \langle n_{\pi^-} \rangle \cdot \langle n_{\pi^0} \rangle. \tag{3.1}$$

Its value can be calculated from the formula:

$$f_2^{0-} = \sum_{n_{\pi^-}} n_{\pi^-} \cdot \langle n_{\pi^0} \rangle_{n_{\pi^-}} \cdot \sigma_{n_{\pi^-}} / \sigma_{\text{inel}} - \langle n_{\pi^-} \rangle \cdot \langle n_{\pi^0} \rangle. \tag{3.2}$$

Our data yield $f_2^{0-} = -0.10 \pm 0.09$ to be compared with -0.03 ± 0.08 obtained for the pp interactions at 12 GeV/c.

We also compared our data with the predictions of a model proposed in Ref. [6]. According to this model, the distribution of total multiplicities is described by the Czyżewski-Rybicki formula (Ref. [7]) and the charge branching ratios are calculated using the isospin weights given by the statistical model (Ref. [8]). The free parameters of the Czyżewski-Rybicki formula, $\bar{n}$ and D, are fitted so as to reproduce correctly the multipli-

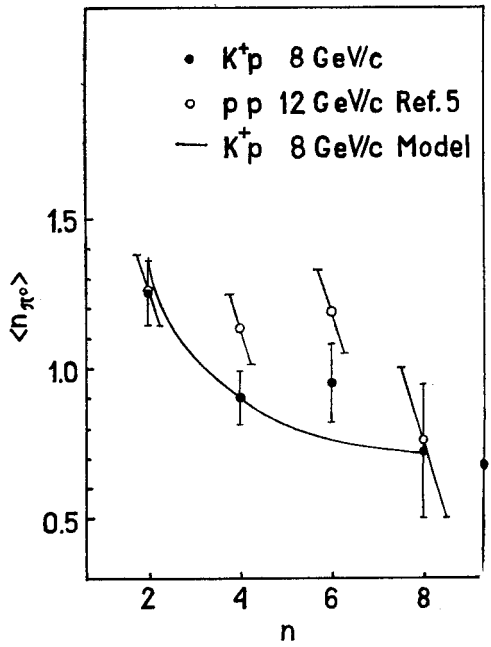

Fig. 1. The average number of π^0 mesons as a function of charged particle multiplicity for K^+p interactions at 8.2 GeV/c, for pp interactions at 12 GeV/c (from Ref. [5]) and calculated from the model of Ref. [6]

city distribution of charged particles. Thus for the multiplicity of π^0 mesons absolute predictions are obtained. As can be seen from Fig. 1, the agreement of the model with the data is very good. The model yields $\langle n_{\pi^0} \rangle = 1.07$ and $f_2^{0-} = -0.16$ which are in good agreement with the experimental values.

3.2. Momentum and energy distributions

The formulae relating the momentum and energy distributions for π^0 mesons with the measured distributions of γ-quanta are given in Ref. [9]. For the first few moments of these distributions these formulae read:

$$\begin{aligned} \langle E_{\pi^0} \rangle &= 2 \cdot \langle E_\gamma \rangle, \\ \langle p_{i,\pi^0} \rangle &= 2 \cdot \langle p_{i,\gamma} \rangle, \\ \langle p_{i,\pi^0}^2 \rangle &= 3 \cdot \langle p_{i,\gamma}^2 \rangle - \tfrac{1}{2} m_\pi^2. \end{aligned} \tag{3.3}$$

Here E_{π^0} and p_{i,π^0} denote the energy and the i-th component of the momentum vector for π^0 mesons. E_γ and $p_{i,\gamma}$ denote the same quantities for photons and m_π denotes the mass of the π^0 meson.

From these relations we calculated for π^0 mesons the average of the energy, of the longitudinal momentum and of its square (all in the centre of mass system), and of the average square of the transverse momentum. It has been checked that the contributions to these averages from the unmeasured and the unreconstructed events are negligible.

TABLE II

The averages of the energy, longitudinal momentum and its square (in centre of mass system) and average square of the transverse momentum of π^0 mesons produced in K^+p interactions at 8.2 GeV/c

Type of interactions	$\langle E_{\pi^0}\rangle$ (GeV)	$\langle p_{L\pi^0}\rangle$ (GeV/c)	$\langle p^2_{L\pi^0}\rangle$ ((GeV/c)^2)	$\langle p^2_{T\pi^0}\rangle$ ((GeV/c)^2)
All	0.466±0.011	0.128±0.013	0.154±0.013	0.116±0.007
2-prong	0.531±0.018	0.192±0.022	0.212±0.021	0.123±0.009
4-prong	0.410±0.016	0.072±0.017	0.100±0.015	0.112±0.011
6-prong	0.381±0.030	0.054±0.030	0.062±0.015	0.097±0.015
8-prong	0.278±0.064	0.077±0.048	0.027±0.033	0.064±0.015

The errors given in the Table are statistical only.

The results for all inelastic K^+p interactions and for given multiplicities of charged particles in the final state are given in Table II. The averages of energy and squared longitudinal momentum of produced π^0-s drop with increasing charged particle multiplicity, while the average square of the transverse momentum is seen to be nearly constant. The average longitudinal momentum is positive and for the two-prong topology much higher than for other multiplicities. Diffractive dissociation $K^+ \to K^+ \pi^0 \pi^0$ could contribute here.

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