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AN INVESTIGATION OF THE INTERACTION OF π-MESONS WITH XENON NUCLEI AT 2.34, 3.5, 5 AND 9 GEV/C

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SUMMARY

An investigation of the characteristics of π^0-mesons, slow π^+-mesons and protons emitted in π^+ - Xe interactions at 2.34 GeV/c and in π^- - Xe interactions at 3.5, 5 and 9 GeV/c has been made.

The results on the π^0-meson and charged particle emission multiplicity as well as the angular and momentum distributions of π^0 - mesons, slow π^+-mesons and protons were obtained.

It was observed that the average multiplicity of π^0-meson production decreased with increasing the number of secondary charged particles, N_{ch}, in π - Xe interactions at 2.34 and 3.5 GeV/c and was constant at 5 and 9 GeV/c.

At all energy values studied the class of π - Xe interactions with small N_{ch}, in which the angular and momentum characteristics of π^0-mesons do not differ from the corresponding pion characteristics produced in π - nucleon collisions at the same energies is clearly observed. A simple statistical interpretation of these phenomena is given. An average value of kinetic energy of protons emitted in π - Xe interactions at 2.34 GeV/c does not depend on the number N_{ch} and is equal approximately to one half of the pion mass. The neutral boson resonance production ($\eta^0 \to 2\gamma$, $3\pi^0$; $\omega^0 \to \pi^0\gamma$) is mostly observed only in π - Xe interactions with small secondary charged particle numbers.

In this paper we present the main results obtained in an investigation of the characteristics of π^0- mesons and charged particles emitted in π -Xe interactions at 2.34, 3.5, 5 and 9 GeV/c. The experiment has been carried out using a xenon bubble chamber.

1. Investigation method

The xenon bubble chamber makes it possible to detect γ - quanta at an energy above a few MeV with an efficiency of about 100% and to measure their energy with an accuracy of $\sim$ 10-20% at a whole solid angle of their emission. It is also possible to identify and measure the energy of slow $\sim$ 10-70 MeV π^+- mesons and $\sim$ 15-220 MeV protons within a 4π angle.

The precision in measuring the point coordinates of the primary interaction and γ - quanta conversion is $\overline{\Delta x} \simeq \overline{\Delta y} \simeq$ $\simeq$ 0.1 mm and $\overline{\Delta z} \simeq$ 0.5 mm. The accuracy in determining the angles is equal to $\sim$ 0.5 - 2°.

2. Experimental results and their discussion

General information on the obtained experimental material is presented in Table I.

2.I. π^0 - production

A mass spectroscopic analysis of the $k \geq 2$ γ-quanta systems accompanying the π^+ - Xe interactions at 2.34 GeV/c as well as the π^- - Xe reactions at 5 and 9 GeV/c shows that π^0 - mesons are a main and almost unique source of γ-quanta [1-4]. Nevertheless, in the interactions with a small number of secondary charged particles $N_{ch} \leq 3$ [1,3], a η^0- meson

Table I

General characteristics of the experimental material. N_{ch} is the number of secondary charged particles; k is the number of γ-quanta.

Reaction	Momentum GeV/c	Number of photographs	Number of selected events	Number of secondary particles			
				γ	π^+	p	N_{ch}
$\pi^+ + Xe \to k\gamma + (N_{ch}=1)$	2.34	500 000	1362	3857	-	1362	1362
$\pi^+ + Xe \to k\gamma + N_{ch}$	2.34	15 000	2343	4468	434	1008	-
$\pi^- + Xe \to k\gamma + N_{ch}$	3.50	20 000	4908	8246	-	-	23734
$\pi^- + Xe \to k\gamma + N_{ch}$	5.00	3 000	250	491	-	-	-
$\pi^- + Xe \to k\gamma + N_{ch}$	9.00	12 000	1743	4735	490	-	-

was observed decaying into 2 γ and 3 π^o. This is particularly true for the interactions with N_{ch} = 0.1. Thus, in the π^++ Xe reaction with the number of γ - quanta k = 2 and N_{ch} = 1

$$R_{\eta^o} = \frac{N_{\eta^o \to 2\gamma}}{N_{\pi^o}} = (24.2 \pm 2.7)\%.$$

A similar value for the π^- - Xe reaction with N_{ch} = 0 at 9 GeV/c is equal to $R_{\eta^o} \lesssim 14\%$. As N_{ch} increases, R_{η^o} markedly diminishes. The production of other particles studied, which decay into π^o- mesons and γ - quanta, is much small.

Table II presents the mean multiplicity of π^o- production in π - Xe interactions with different numbers N_{ch} at 2.34, 3.5, 5 and 9 GeV/c.

Table II

Mean multiplicity $\langle n_{\pi^o} \rangle$ of π^o- production in π- Xe interactions with different numbers N_{ch} of secondary charged particles at 2.34, 3.5, 5 and 9 GeV/c.

$P_{(GeV/c)}$ \ N_{ch}	≤ 3	4 ÷ 6	≥ 7	Total
2.34	0.50 ± 0.04	0.63 ± 0.04	0.39 ± 0.03	0.51 ± 0.02
3.5	1.12 ± 0.07	0.94 ± 0.06	0.66 ± 0.06	0.88 ± 0.03
5	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.2
9	1.5 ± 0.2	1.6 ± 0.3	1.4 ± 0.2	1.5 ± 0.2

Table III is the distribution of the π^+ - Xe interactions at 2.34 GeV/c and π^- - Xe interactions at 9 GeV/c via the number of produced π^o - mesons.

Table III

Distribution of the π^+ - Xe interactions at 2.34 GeV/c and π^- -Xe interactions at 9 GeV/c via the number of produced π^0 - mesons

N_{π^0}	2.34 GeV/c (π^+ + Xe)	9 GeV/c (π^- + Xe)
1	(77.1. ± 5.8) %	(45.5 ± 4.0) %
2	(18.0 ± 2.4) %	(36.5 ± 2.0) %
3	(4.5 ± 1.1) %	(10.1 ± 1.6) %
4	(0.4 ± 0.3) %	(7.4 ± 0.8) %
5	0	(0.5 ± 0.4) %

From the presented data one should conclude that the mean multiplicity $\langle n_{\pi^0} \rangle$ of π^0 - production in π + Xe interactions decreases with increasing N_{ch} at 2.34 and 3.5 GeV/c and remains constant at 5 and 9 GeV/c. It is of interest to note that in the π p and pp reactions $\langle n_{\pi^0} \rangle$ is also constant with increasing N_{ch} at energies above 10 GeV but below 20 GeV[5] while in π^- - C interactions at 40 GeV/c $\langle n_{\pi^0} \rangle$ grows with N_{ch}[6].

The rate of a larger number of π^0 - mesons emitted increases with increasing the interaction energy.

2.2 Interactions accompanied by a small number of charged particles N_{ch}

Those of a large number of the interaction channels of fast pions with Xe nuclei are of especial interest which result in a small number of secondary charged particles emitted. At the same energies these interactions do not differ from the corresponding pion-nucleon ones in the characteristics of secondary

particles: angular and momentum distributions of π^0- mesons, average numbers of secondary particles and proton momentum distribution. The number N_{ch} is a selection criterion of these so-called quasi-free interactions: $N_{ch} \leq 3$ in π^+ + Xe interactions at 2.34 GeV/c and $N_{ch} \leq 4$ in π^- + Xe interactions at 5 and 9 GeV/c. In Table IV one can see the parts of quasi-free interactions relatively all the inelastic reactions π + Xe at various energies. The same table presents similar data which were obtained using nuclear photoemulsions.

Table IV

Fraction P of quasi-free interactions in different reactions and at various energies.

Reaction	Momentum (GeV/c)	P (%)
π^+ + Xe	2.34	33.6 ± 3.0
π^- + Xe	5	27.2 ± 3.2
π^- + Xe	9	27.2 ± 3.7
P + emulsion nuclei	8.7	25[7]
π^- + emulsion nuclei	16.3	<39[8]
π^- + emulsion nuclei	67	>17[9]

From the presented data one can conclude that the fraction P of quasi-free interactions via the reactions of π-mesons with Xe nuclei is independent, within errors, of the energy and is equal approximately to 30% of all π + Xe inelastic reactions. This conclusion does not contradict the corresponding data obtained by means of nuclear emulsions[7-9]. The performed analysis of the probability function of meson production on single intra-

nuclear nucleon, when secondary inelastic interactions are absent, shows[11] that a similar picture should hold for medium and heavy nuclei at higher energies as well. The calculated fractions of quasi-free interactions in the π^+ + Xe reaction at 2.34 GeV/c is equal to 29%[11]. This is in good agreement with experimental data.

2.3. Charged particle emission

Table V is the N_{ch} distribution of π^- + Xe interactions with an arbitrary number of γ - quanta and with $k = 0$ at 3.5 GeV/c.

Table V

N_{ch} distribution of π^+ + Xe interactions at 3.5 GeV/c. k is the number of γ - quanta

k \ N_{ch}	0	I	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
0	8	230*)	206	213	217	209	196	218	169	145	93	50	21	10	9	1994
All	72	462	598	668	645	608	488	466	334	264	166	82	35	11	9	4908

Taking into account the peculiarity of quasi-free interactions (2.2), the following probability density function[10] was proposed for describing the obtained experimental data:

$$p(n+1) = \left(0.3\cdot\lambda_1\frac{e^{-\lambda_1}}{n} + 0.7\cdot\lambda_2\frac{e^{-\lambda_2}}{n}\right)(1-\alpha) + \alpha\cdot\delta_{1,n}, \quad \text{(I)}$$

where $\delta_{1,n}$ is the Kronekker symbol. In addition, it was supposed that the particle emission in π^- + Xe interactions with a large number of secondary particles is also described by the Poisson function. The coefficient α takes into account the elastic scattering events at an angle of $\gtrsim 5^\circ$.

Function (I) satisfactorily describes the distribution of the π^+ + Xe interactions studied via the summary number of particles at different k. Except for the case with $k = 0$, the agreement is much worse for the corresponding N_{ch} distributions of secondary charged particles.

*) Events in which the scattering angle projection of a charged particle onto the photographing plane is not less than 5°.

2.4. Proton emission

Table VI presents the mean values of the momenta and forward-backward asymmetry coefficient of proton emission in the π^+ + Xe interactions at 2.34 GeV/c.

Table VI

Mean values of the proton momenta P in the π^+ + Xe interactions at 2.34 GeV/c and the ratio of the forward (F) to the backward (B) emission rate.

N_{ch}	$\leqslant 3$	4 • 6	7 • 9	$\geqslant 10$
P MeV/c	360 ± 20	348 ± 17	350 ± 15	322 ± 20
F/B	2.4 ± 0.2	1.6 ± 0.2	2.0 ± 0.2	

The mean momentum of protons emitted does not depend on N_{ch} and corresponds to the kinetic energy of protons approximately equal to one half the pion mass. The proton emission rate strongly grows with increasing N_{ch}. The simplest explanation of this phenomenon lies in the assumption that the nucleon emission in the considered interactions occurs mainly due to two-nucleon absorption of slow pions inside the nucleus. That the emission rate of π°-mesons does not increase and their energy markedly diminishes with increasing N_{ch} is not in contradiction with this assumption.

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