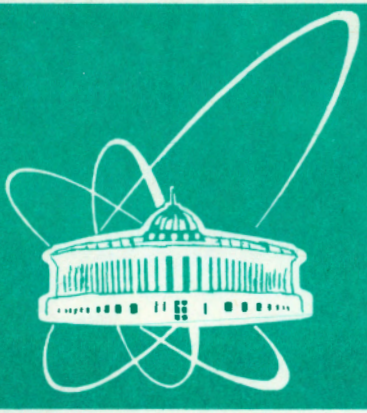

сообщения
объединенного
института
ядерных
исследований
дубна

E1-93-419

Z.Strugalski[1], A.Dessoky, E.Mulas[2],
E.Strugalska-Gola[3]

CHARACTERISTICS OF GAMMA-QUANTA EMISSION PROCESS IN Π^- + Xe NUCLEAR COLLISIONS AT 3.5 GeV/c MOMENTUM

[1]Permanent address: Warsaw University of Technology,
Institute of Physics, ul.Koszykowa, 75, 00-662 Warsaw, Poland
[2]Warsaw University of Technology, Institute of Physics, Plock, Poland
[3]Space Research Center, Polish Academy of Sciences, Warsaw, Poland

1993

1. INTRODUCTION

The aim of this work has been to gain insight in the physics of the gamma-quanta emission process in hadron-nucleus collisions; first of all, the relation between characteristics of the gamma-quanta and of the parent neutral pions produced in the collisions is studied here experimentally. This work is a continuation of our paper on the characteristics of the parent neutral pion production process in the nuclear collisions [1].

Similarly, as in the previous work [1], we prepared the characteristics of the gamma-quanta emission process in dependence on how much the target nucleus in the hadron-nucleus collision is involved; the multiplicity n_p of the protons emitted from the target nucleus indicates it well enough [2].

We hope that the results obtained in this work will be useful for the astrophysics and for the gamma-astronomy as well — in particular, as a physical basis for adequate methods.

2. EXPERIMENT

The xenon bubble chamber [3], built as the rectangular parallelepiped of $104\times40\times43$ cm^3 volume, without magnetic field, has been used in this experiment. The chamber is practically 4π solid angle detector recording produced PiO mesons with the efficiency near to 100% at the total diapason of their kinetic energy values, starting from 0 MeV. The beam and exposure, and all the experimental procedure — scanning and measurements especially, are described in detail in our previous work [1].

A sample of the 6301 pion-xenon nucleus collision events with any number of secondaries forms experimental basis of this work.

3. EXPERIMENTAL DATA

In the sample, the 6301 pion-xenon nucleus collision events satisfying the scanning criteria were recorded on about 80000 chamber photographs; total number of 10634 gamma-quanta were recorded and 3584 neutral pions were identified. The energies and emission angles of every of the quanta were measured; the minimum value of the energy of the gamma-quanta registered with a constant efficiency amounts about 5 MeV. The accuracy of estimation of the emission angle is about 1°; and of energy measurement [4,5], is 5—12%.

Below, the multiplicity n_γ, or the gamma-quanta emission intensity, energy E_γ and momentum P_γ spectra, and the angular distribution of the emitted quanta are presented. Additionally, information about PiO production will be confronted to the information about gamma-quanta emission, appearing in decaying the produced PiO mesons.

3.1. Intensity of the Gamma-Quanta Emission

The gamma-quanta multiplicity n_γ in any of the hadron-nucleus collisions characterizes the gamma-quanta emission intensity. In fig.1, the n_γ distribution $N/\Sigma N$ is shown, as obtained experimentally; not any corrections for the quanta registration efficiency were involved. From this distribution, it can be concluded that the gammas are ejected in even numbers — two or four gammas per collision event are ejected predominantly and, therefore, simple correlation of the pairs of gamma-quanta into effective mass $m_{\gamma_i\gamma_j}$:

$$m^2_{\gamma_i\gamma_j} = 2E_{\gamma_i}E_{\gamma_j}(1-\cos\theta_{\gamma_i\gamma_j}) \qquad (1)$$

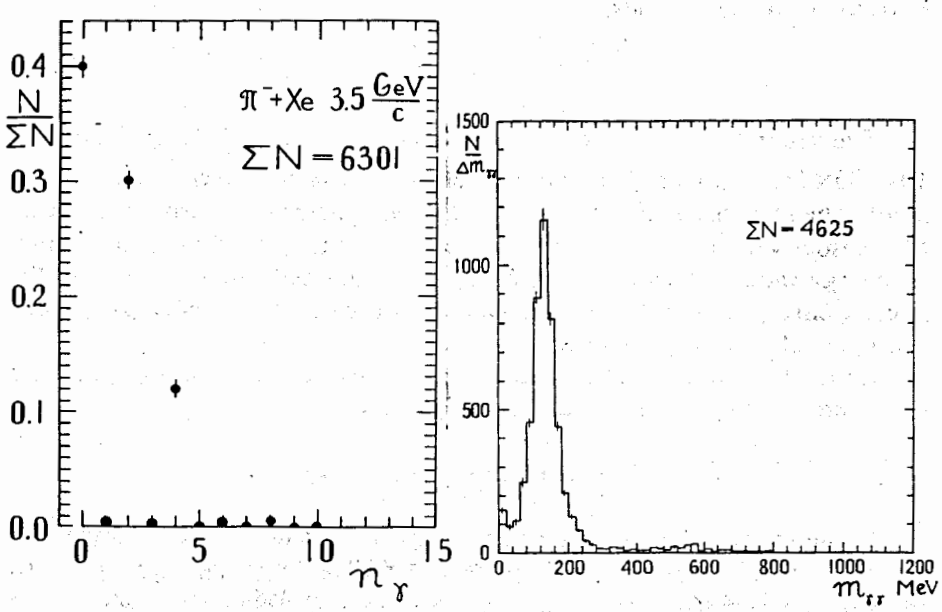

Fig.1. The distribution $N/\Sigma N$ of the multiplicity n_γ, or intensity, of gamma-quanta which the π^-Xe collisions at 3.5 GeV/c are accompanied by; not any corrections for the quanta registration were involved

Fig.2. The distribution of the values $m_{\gamma\gamma}$ of effective masses, Eq.(1), from pairs of gamma-quanta ejected in π−Xe nucleus collisions at 3.5 GeV/c. ΣN — total number of events

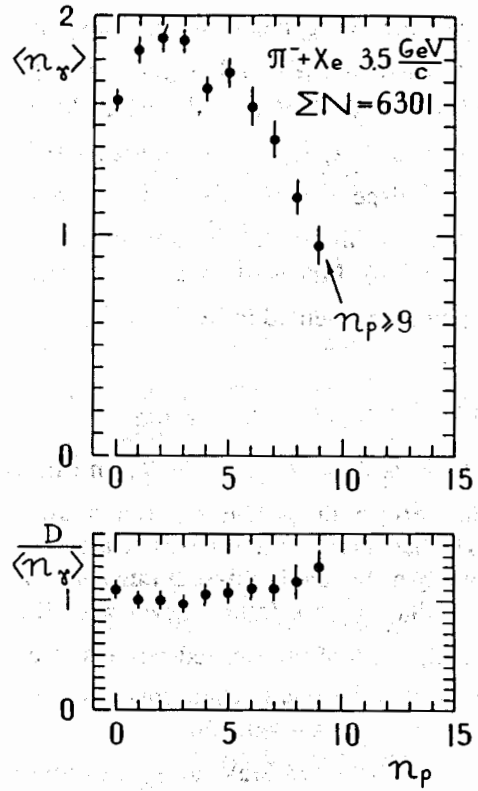

Fig.3.The proton multiplicity n_p, or intensity, dependence of the mean multiplicity $\langle n_\gamma\rangle$, or intensity, of the emitted gamma-quanta, in the pion-xenon collision reactions — in the classes of events with $n_p = 0, 1, 2, 3,\ldots$; $D/\langle n_\gamma\rangle$ — the normalized dispersion in dependence on n_p

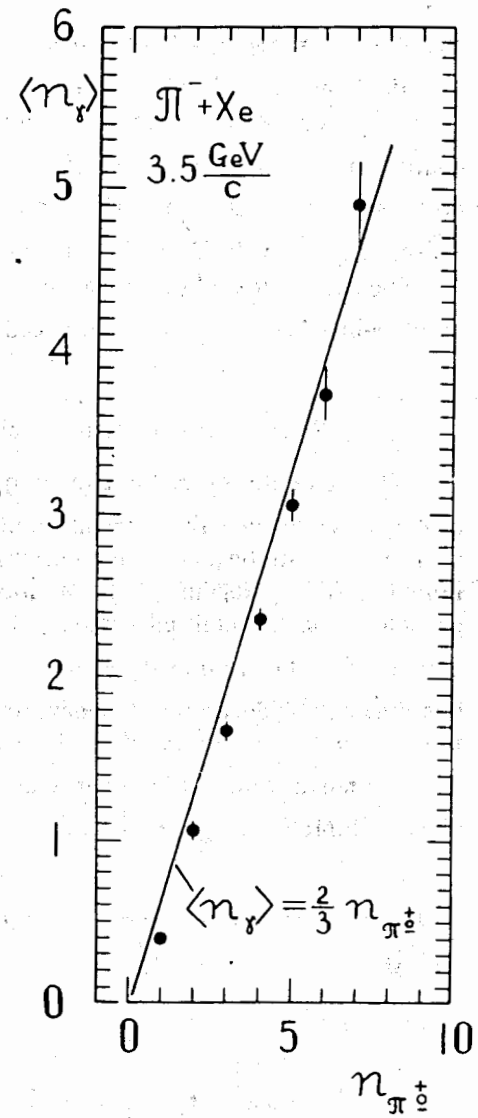

Fig.4. The dependence of the mean multiplicity $\langle n_\gamma\rangle$ of the emitted gamma-quanta on the multiplicity n_{π^0} of the produced pions

may be performed, where E_{γ_i} and E_{γ_j} are energies of an i-th and j-th of the two gamma-quanta, $i = j$; $\theta_{\gamma_i\gamma_j}$ is the angle between the emission directions of the gammas.

The distribution of the $m_{\gamma_i\gamma_j}$ effective mass values is shown in fig.2. It is evident from this histogram that the gammas are predominantly from the produced PiO mesons decays — the peak within about 80—180 MeV values; very

small admixture is presented from η^0 decay into four gammas, in the final state [6]; the admixture of the η^0 decaying into 2 gammas is less than about 5%. In fig.3, the dependence of the mean multiplicity $\langle n_\gamma \rangle$ of the emitted gamma-quanta on the intensity, or multiplicity, $n_p = 0, 1, 2, 3,...$ of the emitted target protons is shown; $D/\langle n_\gamma \rangle$ — the normalized dispersion D in dependence on n_p is presented, as well, for π+Xe collision reactions at 3.5 GeV/c momentum.

The dependence of the mean multiplicity $\langle n_\gamma \rangle$ of the emitted gamma-quanta on the multiplicity $n_{\Pi^{\pm}_{0}}$ of the produced pions is presented in fig.4.

3.2. Energies and Momenta of the Emitted Gamma-Quanta

The mean energy of the gamma-quanta is $E_\gamma = 160 \pm 11$ MeV, and it is exactly equal to one half the mean kinetic energy of the produced parent neutral pions [1], for all the pion-xenon nucleus collisions events at 3.5 GeV/c momentum. The energy depends on the multiplicity of the emitted target nucleons, in particular, on the emitted protons; the values E_γ are falling down with the increasing of the multiplicity $n_p = 0, 1, 2, 3,... \geq 9$ of the emitted protons — as it is shown in fig.5a. Similarly behave themselves the mean longitudinal momentum $P_{\gamma\,11}$ and the mean transverse momentum $P_{\gamma\perp}$, fig.5b and 5c.

The mean values of the energy are from about 175 MeV, at $n_p \geq 0$, up to about 130 MeV, at $n_p = 8$; the values of the longitudinal momentum are from

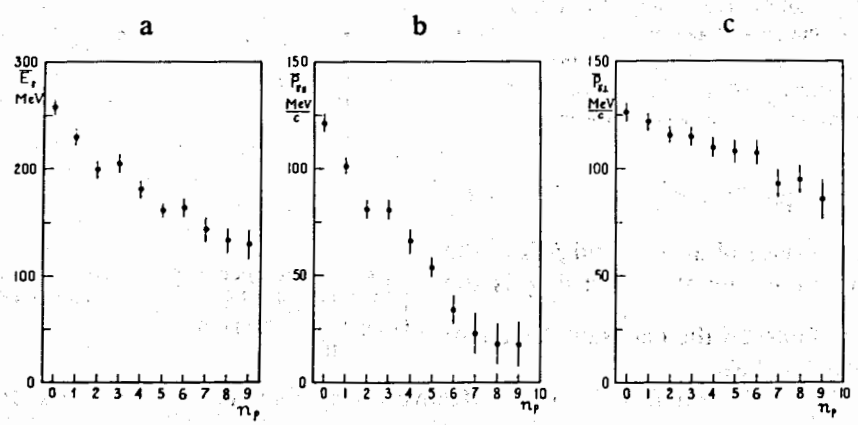

Fig.5. Mean energy E_γ, mean longitudinal momentum $\overline{P}_{\gamma 11}$, mean transverse momentum $\overline{P}_{\gamma\perp}$ of the emitted gamma-quanta, in the classes of pion-xenon nucleus collisions with various numbers $n_p = 0, 1,...$ of the protons emitted from the target nucleus

about 100 MeV/c, at $n_p \geq 0$, up to about 25 MeV/c, at $n_p = 8$; the values of the transverse momentum are from about 150 MeV/c, at $n_p \geq 0$, up to about 80 MeV/c, at $n_p = 8$.

3.3. Angular Distributions of Gamma-Quanta

The mean value of the *cosine* of the gamma-quanta emission angle θ_γ is $\langle \cos\theta_\gamma \rangle = 0.4172$; the value for the parent neutral pions is $\langle \cos\theta_{\pi^0} \rangle = 0.4527$, and for the $\Pi^{\pm}_{0}$ pions it is $\langle \cos\theta_{\Pi^{\pm}_{0}} \rangle = 0.5569$.

The mean value of the $\cos\theta_\gamma$ depends on the number $n_p = 0, 1, 2, 3,...$ of the protons emitted from the target nucleus, table 1; the n_p-dependence of the $\langle \cos\theta_\gamma \rangle$ is similar to the n_p-dependence of the $\langle \cos\theta_{\pi^0} \rangle$ — for the parent Π^0 mesons, table 2.

In table 3, the mean values of θ_γ, θ_{π^0} and $\theta_{\Pi^{\pm}_{0}}$ emission angles are confronted mutually — for comparison.

Table 1. Mean values $\langle \cos\theta_\gamma \rangle$ of the cosine of the gamma-quanta emission angle θ_γ, in events with various multiplicity $n_p = 0, 1, 2,..., 8, 9 \geq 0$, in the sample of pion-xenon nucleus collisions at 3.5 GeV/c momentum

n_p	Entries	All channels	$\langle \cos\theta_\gamma \rangle$	r.m.s.	Skewness	Kurtosis
0	2093	2172	0.5952	0.4767	−1.1541	1.536
1	2052	2152	0.5159	0.5032	−1.242	0.5639
2	1708	1799	0.4362	0.5346	−0.9747	−0.1087
3	1371	1444	0.3875	0.5579	−0.8657	−0.3850
4	990	1049	0.3061	0.5746	−0.6538	−0.7766
5	932	1016	0.3132	0.5523	−0.6157	−0.7625
6	664	709	0.2147	0.5923	−0.4136	−1.054
7	389	414	0.2399	0.5773	−0.5133	−0.9475
8	230	245	0.1214	0.5830	−0.2194	−1.131
9	205	218	0.0569	0.6033	0.0386	−1.363
≥ 0	10634	11220	0.4172	0.5518	−0.9178	−0.3051

Table 2. Mean values $\langle \cos \theta_{\pi^0} \rangle$ of the cosine of the π^0 meson emission angle, in events with various multiplicity $n_p = 0, 1, 2, \ldots$ of the protons emitted from the target nucleus in $\Pi-Xe$ collisions at 3.5 GeV/c momentum

n_p	Entries	All channels	$\langle \cos \theta_{\pi^0} \rangle$	r.m.s.	Skewness	Kurtosis
0	711	770	0.6378	0.4392	−1.642	1.937
1	682	753	0.5596	0.4702	−1.384	1.063
2	574	641	0.4650	0.4959	−1.055	0.2434
3	472	523	0.4350	0.5237	−1.039	0.1098
4	334	379	0.3835	0.5225	−0.7831	−0.5005
5	310	374	0.3388	0.5382	−0.5879	−0.7265
6	238	272	0.1930	0.5771	−0.2825	−1.100
7	128	147	0.2175	0.5703	−0.4917	−0.8780
8	70	79	0.2158	0.5880	−0.4018	−1.289
9	65	74	0.0566	0.6108	−0.1678	−1.179
≥ 0	3584	4011	0.4527	0.5249	−0.9957	−0.0654

Table 3. Mean values of the emisson angles θ^0 of Π^{+}_{0} mesons, Π^0 mesons and gamma-quanta in $\Pi-Xe$ nucleus collision events with various multiplicities $n_p = 0, 1, 2, 3, \ldots$ of the protons emitted from the target nucleus

n_p	$\langle \theta^0_{\gamma} \rangle$	$\langle \theta^0_{\Pi^{+}_{0}} \rangle$	$\langle \theta^0_{\Pi^0} \rangle$
0	53	43	50
1	59	49	56
2	64	55	62
3	67	59	64
4	72	61	67
5	71	65	70
6	77	67	78
7	76	67	77
8	83	69	77
≥ 9	86	75	86
≥ 0	65	56	63

4. CONCLUSIONS AND REMARKS

Let us sum up the main results obtained in this work. It should be concluded that in pion-xenon nucleus at 3.5 GeV/c momentum:

1. Practically all the emitted gamma-quanta are emitted in even numbers – $n_\gamma = 2, 4, 6, 8$; some of collision events — in about 40% — are without secondary PiO mesons, fig.1.

2. The gamma-quanta are predominantly from the Π^0 meson decays into 2 gammas; only η^0 are additional, but very rarely, represented source — in less than about 5% of the population, fig.2.

3. The mean multiplicity $\langle n_\gamma \rangle$ of the emitted quanta changes with the multiplicity n_p of the target protons emitted in a collision. This multiplicity increases from about $\langle n_\gamma \rangle \cong 1.6$ at $n_p = 0$ up to about $\langle n_\gamma \rangle \cong 2$ at $n_p = 2$, and it is falling down at larger values $n_p > 2$ — up to about $\langle n_\gamma \rangle \cong 1.6$ at $n_p = 4$; it increases up to about $\langle n_\gamma \rangle \cong 1.8$ at $n_p = 5$ and it is falling down starting from this point up to $\langle n_\gamma \rangle \cong 0.9$ at $n_p \geq 9$, fig.3.

Such behaviour of the $\langle n_\gamma \rangle$ dependence on n_p repeates qualitatively the behaviour of the parent Π^0 mesons multiplicity $\langle n_{\pi^0} \rangle$ in dependence on n_p, as it can be concluded from corresponding fig.4 in our previous paper [1].

4. Simple relation between the mean multiplicity $\langle n_\gamma \rangle$ and the multiplicity $n_{\Pi^{+}_{0}}$ of the produced pions is stated experimentally:

$$\langle n_\gamma \rangle = \frac{2}{3} n_{\Pi^{+}_{0}}, \qquad (2)$$

in fig.4.

5. The mean energies E_γ, mean longitudinal momenta $P_{\gamma\,\parallel}$, and mean transverse momenta $P_{\gamma\perp}$ of the emitted gamma-quanta decrease with increasing of the multiplicity n_p of the protons emitted from the target nucleus in the hadron-nucleus collision reaction, fig.5.

Qualitatively, similar behaviour is observed in corresponding dependences for the parent neutral pions, see figs.5,9, and 12 in our former work [1].

6. Angular distributions of the emitted gamma-quanta are very similar to those distributions for the parent Π^0 mesons. In order to reveal a possible influence of the Π^0 meson production on the nucleon emission from the target nucleus, appropriate dependences of the nucleon, or proton only, emission cha-

racteristics on the multiplicity n_γ of the emitted gamma-quanta should be obtained and analysed in our next work. The characteristics of the target nucleon emission on the multiplicity of the produced Π^0 mesons, n_{π^0} will be analysed as well from the point of view in question; instead of the characteristics of the proton emission on the multiplicity of n_{π^0}, the dependences of the proton emission characteristics on the multiplicity $n_{\Pi^0_e}^+$ might be used.

REFERENCES

1. Strugalski Z. et al. — Characteristics of Neutral Pion Production Process in Π^- + Xe Nuclear Collisions at 3.5 GeV/c Momentum, JINR, E1-90-459, Dubna, 1990.
2. Strugalski Z., Pawlak T., Pluta J. — JINR, E1-85-888, Dubna, 1985.
3. Kusnetsov E.V. et al. — Instrumentation and Methods, Sov. Journ. PTE, 1961, 6, p.26.
4. Strugalski Z. — JINR Preprint, No.796, Dubna, 1961; Konovalova L.P., Okhrimenko L.S., Strugalski Z.S. — Nucl. Instrum. and Methods (Russian), 1961, 6, p.26.
5. Strugalski Z. — Detection and Energy Measurement of Gamma-Quanta and Electrons. T.E.P.P., Ecole Internationale de la Physique des Particles Elementaries, Strasbourg — Belgrade, 1971.
6. Abrosimov A.T. et al. — JINR, R1-12563, Dubna, 1979.

Received by Publishing Department
on November 22, 1993.

Стругальский З. и др. E1-93-419

Характеристики процесса испускания гамма-квантов
в ядерных столкновениях Π^- + Xe при 3,5 ГэВ/с

Характеристики процесса испускания гамма-квантов: интенсивность испускания, энергетические и угловые спектры, импульсные распределения — получены в почти полном эксперименте, выполненном с помощью 180-литровой ксеноновой пузырьковой камеры, облученной в пучке отрицательно заряженных П-мезонов при 3,5 ГэВ/с. Наблюдается зависимость характеристик от толщины слоя внутриядерной материи, вовлеченного в столкновения. Проведено сравнение характеристик испущенных квантов с соответствующими характеристиками родительских нейтральных мезонов.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 1993

Strugalski Z. et al. E1-93-419

Characteristics of Gamma-Quanta Emission Process
in Π^- + Xe Nuclear Collisions at 3.5 GeV/c Momentum

Characteristics of the gamma-quanta emission process: emission intensity, energy and momentum spectra, and angular distributions have been obtained experimentally in almost total experiment performed by means of the 180 litre xenon bubble chamber exposed to 3.5 GeV/c momentum negatively charged pion beams. The dependence of the characteristics on the internuclear matter layer thickness involved in the collisions is evidently observed. Comparisons between the characteristics of the emitted quanta and the corresponding characteristics of the parent neutral pions are performed.

The investigation has been performed at the Laboratory of High Energies, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1993