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PROTON SPECTRA IN HIGH-ENERGY PION-NUCLEI COLLISIONS NOT ACCOMPANIED BY MULTIPARTICLE PRODUCTION

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PROTON SPECTRA IN HIGH-ENERGY PION-NUCLEI COLLISIONS NOT ACCOMPANIED BY MULTIPARTICLE PRODUCTION

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Спектры протонов в пион-ядерных соударениях высоких энергий, не сопровождаемых множественным рождением частиц

В статье даются кратностные, энергетические и угловые распределения протонов с энергиями выше 20 МэВ, испущенных в пион-ксеноновых соударениях при 3,5 ГэВ/с, не сопровождаемых множественным рождением частиц. Показана асимметрия в азимутальном распределении протонов, видна немонотонность в распределении протонов по кратностям.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1978

Strugalski Z. et al. **E1 - 11975**

Proton Spectra in High-Energy Pion-Nuclei Collisions not Accompanied by Multiparticle Production

Multiplicity, energy, and angular distributions of protons of energies over 20 MeV emitted in pion-xenon nuclei collisions at 3.5 GeV/c are presented in reactions not accompanied by the multiparticle production. Asymmetry is shown in the azimuth angle distribution of protons; inmonotony of proton multiplicity distribution is seen.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1978

1. INTRODUCTION

Long ago we have observed such collisions of pions with xenon nuclei at 3.5 *GeV/c* in which fast protons, of kinetic energy from about 20 *MeV* to about 400 *MeV*, are intensively emitted without secondary pion emission /1/. An example of such event is shown in *fig. 1*. The protons being not the commonly known evaporation protons are emitted with the average multiplicity $\bar{n}_p = 7.8$. Similarly, the events of pion-nuclei collisions with only one secondary pion and any number of fast protons emitted can be attributed to such type of cases.

Additional qualitative analysis of these events indicates that different characteristics of fast protons following from the accurate investigation of such collisions can suffer important information for a more fundamental understanding how the fast hadron penetrates into the nuclear matter. These gives us a clue as to the direction in which we should try to understand the emission process of the fast protons and proceed. It has often been suggested that the number of fast protons in high-energy hadron-nucleus reactions is a good measure of the number of collisions inside the nucleus /2/. Therefore, more detailed investigations of above named collisions, especially of such their characteristics as proton multiplicity, energy and angular distributions of protons emitted, have been performed.

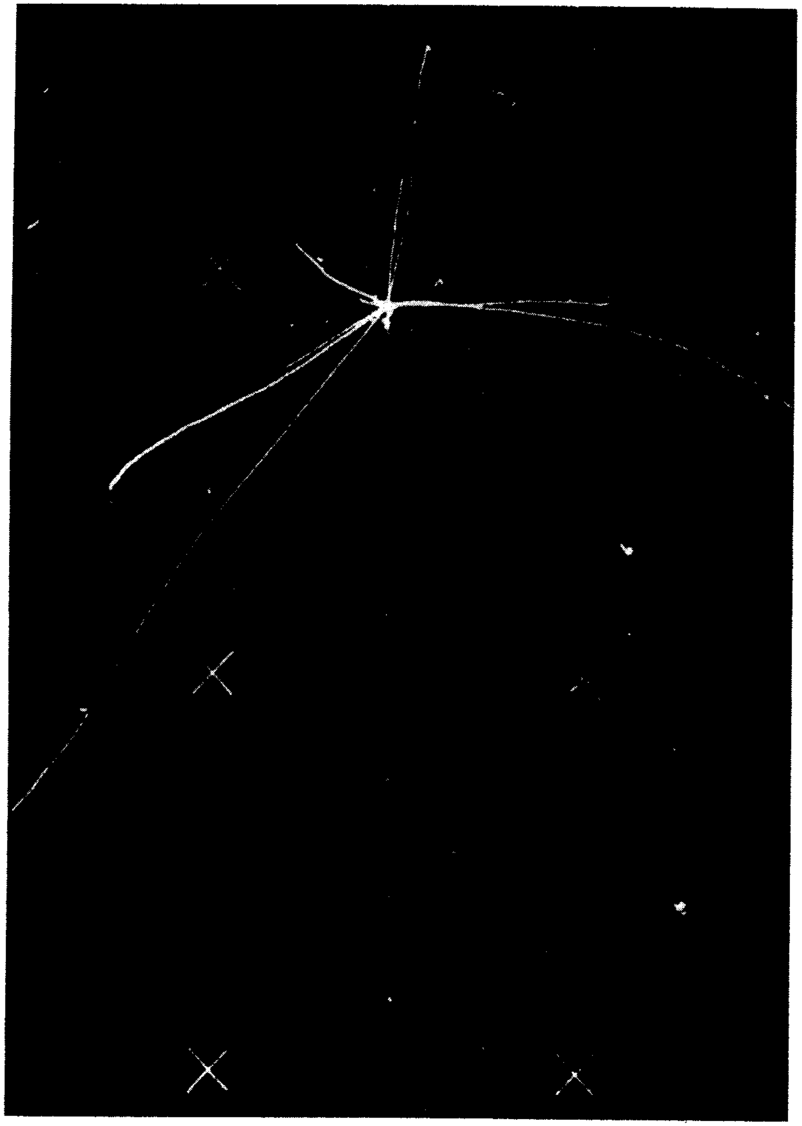

Fig. 1. Collision of negative pion of 3.5 GeV/c momentum with xenon nucleus, not accompanied by the multiparticle production; all secondaries are protons.

2. METHOD OF INVESTIGATION

The photographs of the xenon bubble chamber of the volume 100x40x40 cm^3 irradiated along its big axis in 3.5 *GeV/c* negative pion beam were scanned in order to select the pion-nuclei collisions with zero and one secondary pion and arbitrary numbers of fast protons.

Nearly 100% registration efficiency of the neutral pions in their total energy range, and about 100% effectiveness of identification of practically all positive pions, taking into account the sequence of the tracks of their decay products, give the possibility of stating that the events singled out are in fact the cases of the proton emission without multiparticle production.

In all events selected the energies of protons were estimated with an accuracy of 1-10%, by measuring the track lengths, and their emission angles were measured with an accuracy of about 1-8°. In most cases the average accuracy of the emission angle measurement is nearly 3° and that of energy estimation, almost 4%.

More information concerning the method of investigation of pion-nuclei collisions registered in xenon bubble chamber are published in our other papers /3,4/.

3. EXPERIMENTAL DATA

A sample of 283 events with one secondary pion and 35 events with zero secondary pions were singled out from the total number 2800 of the pion-nuclei collisions.

The proton multiplicity distribution in all the 318 events is shown in *fig. 2a*; similarly, the proton distribution according to multiplicities in the events without secondary pions is presented in *fig. 2b*.

The energy spectra of protons, in total number of events with one and zero secondary pions, and separately in the events with zero secondary pions, are presented in *fig. 3*.

The angular characteristics of the fast protons emitted are shown in *figs. 4,5* and *6*. In *fig. 4* the distribution of proton emission angles is drawn. In *fig. 5* the distribution

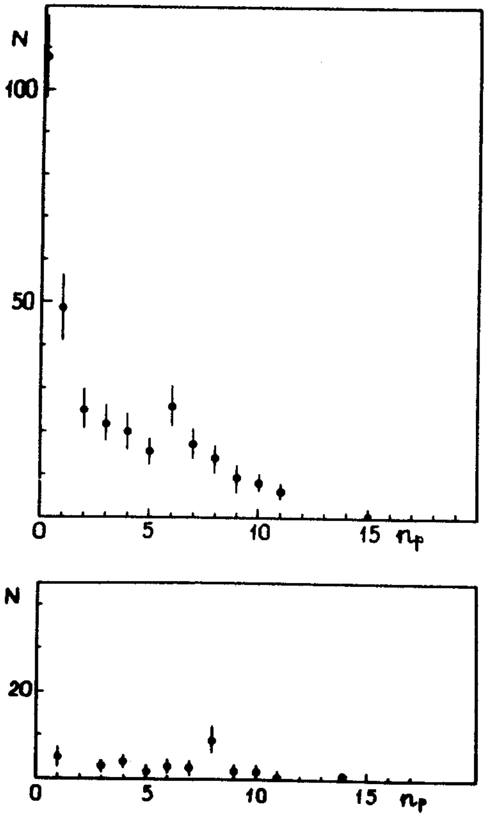

Fig. 2. Distribution of fast proton multiplicities in pion-xenon nuclei collisions at 3.5 GeV/c not accompanied by the multiparticle production: a) in the cases with zero and one secondary pion (upper); b) in the cases with zero secondary pion only (lower).

of azimuth angles of the proton emission directions - the angles between the proton track projection on the plane perpendicular to the primary pion track and the reaction plane containing the tracks of primary and secondary pions - is shown. In *fig. 6* the spectra of the projections of the proton track zenith angles on the reaction plane and separately on the plane perpendicular to it and containing the primary pion track are presented.

This set of characteristics of the pion-nuclei collisions being under consideration, presented in *fig. 2-6*, allows

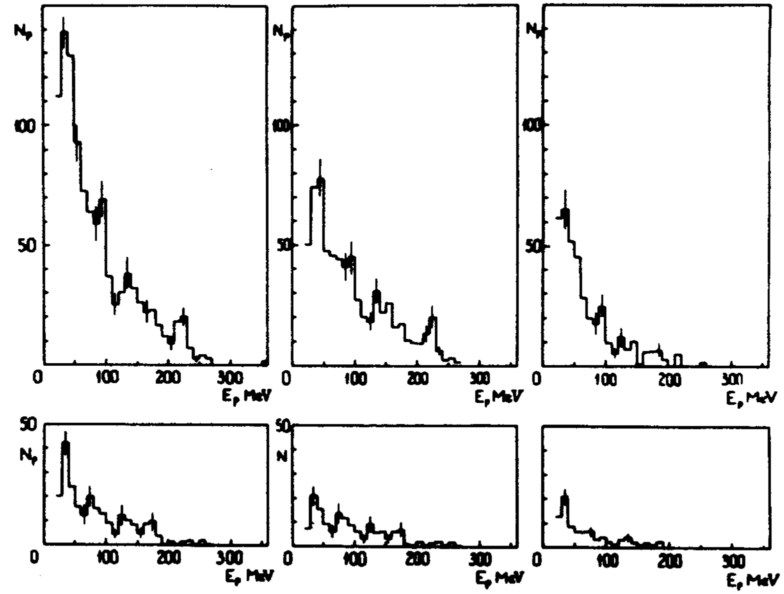

Fig. 3. Energy spectra of the fast protons emitted in pion-xenon nuclei collisions at 3.5 GeV/c not accompanied by the multiparticle production; a) for all events with zero and one secondary pion and for protons emitted in all directions, forward, and backward (upper, from the left to the right); b) for the events with zero secondary pion and for protons emitted in all directions, forward, and backward (lower, from the left to the right).

to reconstruct the picture of the proton emission process. We shall consider the most important features of it.

4. DISCUSSION AND RESULTS

The proton multiplicity distribution of all the collision events with one and zero secondary pion is evidently inmonotonous, *fig. 2*; irregularity is seen at proton number $n_p = 6$. In such distribution of the cases without secondary pions a pick begins to show at $n_p = 8$. These irregularities must be ascribed to the mechanism of the proton emission process in pion-nuclei collisions.

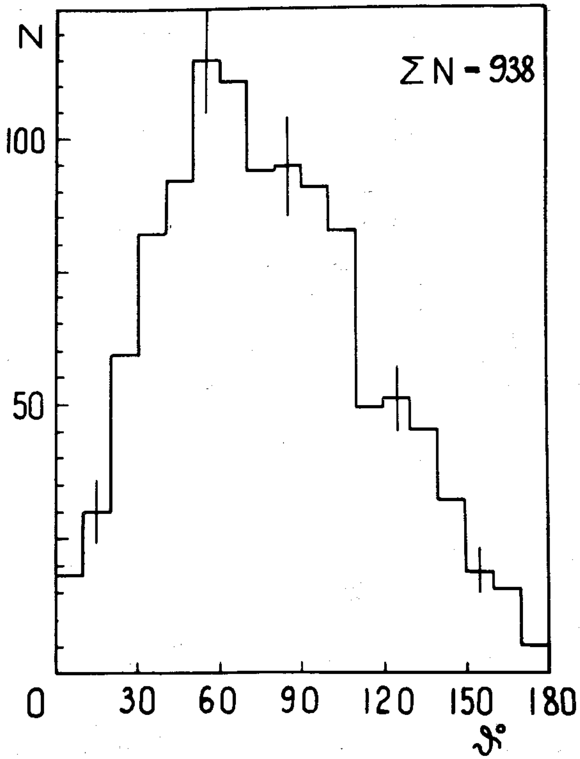

Fig. 4. Angular distribution of the fast protons in pion-xenon nuclei collisions at 3.5 GeV/c without the multi-particle production.

The energy spectra of fast protons emitted forward and of those emitted in backward direction, *fig. 3*, are lying in practically the same kinetic energy intervals 20-250 *MeV*. The ratio k_t of the number N_f of protons emitted in the forward direction to the number N_b of those in backward direction equals

$$k_t = N_f / N_b = 1.78 \pm 0.11 \qquad (1)$$

in the sample of all 318 events, and

$$k_0 = N_f / N_b = 1.69 \pm 0.20 \qquad (2)$$

in events with zero secondary pions.

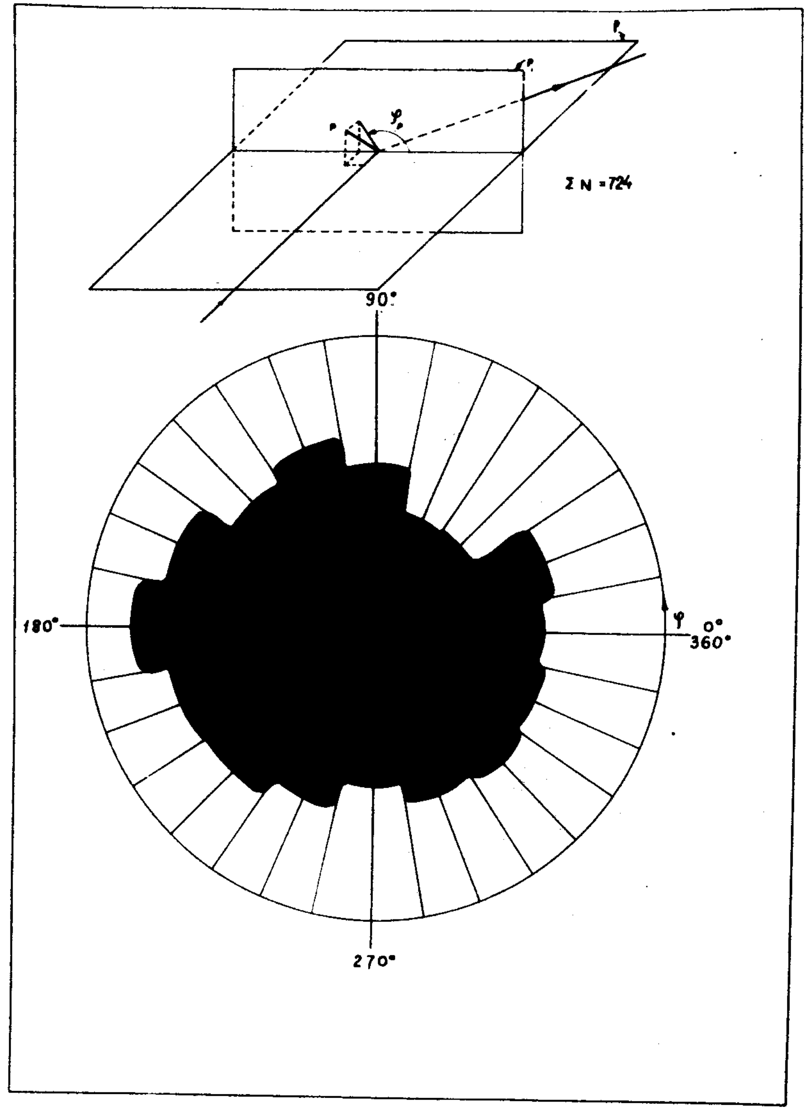

Fig. 5. Distribution of azimuth angles of the fast protons emission directions - the angles between the proton track projection on the plane P_1 *perpendicular to the primary pion track and the reaction plane* P.

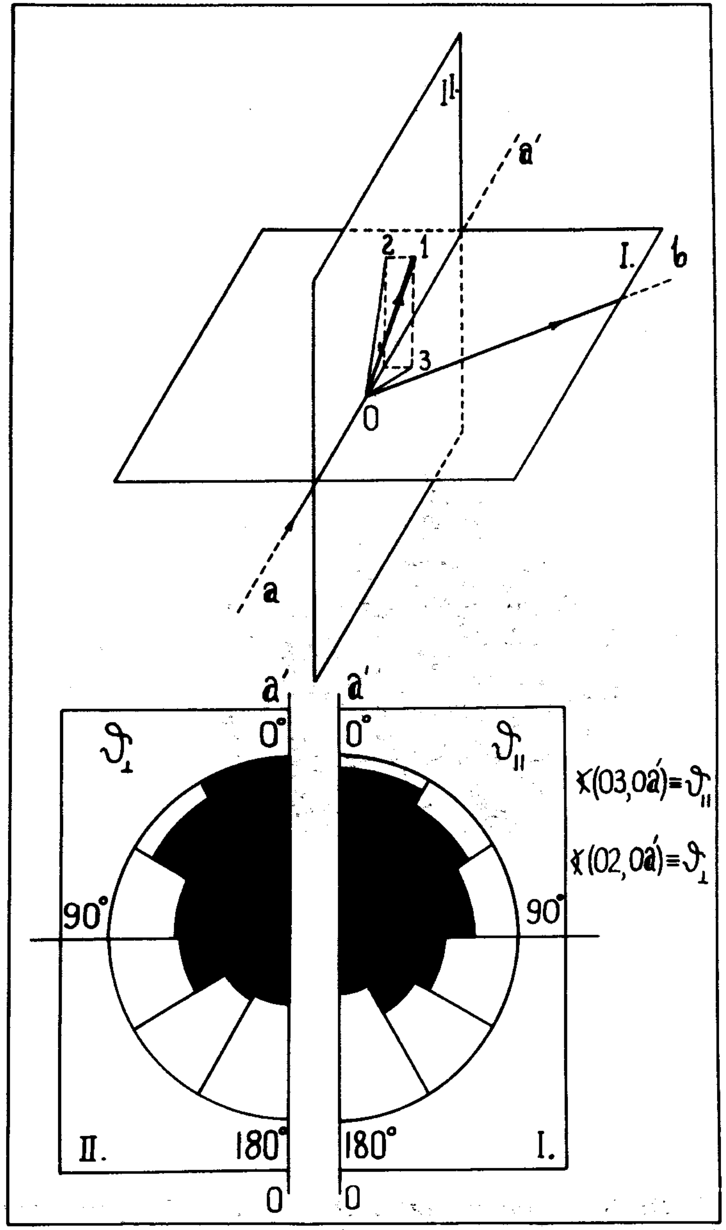

Fig. 6. Distributions of the proton track zenith angle projections on the reaction plane I and on the perpendicular to it plane II.

Asymmetry is observed in the azimuth distribution of proton emission directions, *fig. 5*, especially evidently visible in the interval of angle values $\Delta\phi_1 = (0 \pm 11.25)^\circ$ and $\Delta\phi_2 = (180 \pm 11.25)^\circ$. This asymmetry expressed by the ratio n of the number N_{ϕ_2} to the number N_{ϕ_1} of protons in the angular values region $\Delta\phi_2$ and $\Delta\phi_1$ correspondingly is given in the *table*. It depends on the value of the azimuth angle ϕ.

Table

The dependence of the asymmetry n of the azimuth distribution of proton emission directions on the azimuth angle ϕ

$\Delta\phi_1 = (0 \pm \Delta\phi)^\circ$	$\Delta\phi_2 = (180 \pm \Delta\phi)^\circ$	$n = N_{\phi_2}/N_{\phi_1}$
$(0 \pm 11.25)^\circ$	$(180 \pm 11.25)^\circ$	1.66 ± 0.15
$(0 \pm 33.75)^\circ$	$(180 \pm 33.75)^\circ$	1.20 ± 0.10
$(0 \pm 56.00)^\circ$	$(180 \pm 56.00)^\circ$	1.21 ± 0.10
$(0 \pm 78.50)^\circ$	$(180 \pm 78.50)^\circ$	1.24 ± 0.10

It begins to show, although less evidently and statistically insignificant for the time, the unsimilarity in the distributions of the angular proton track projections on the reaction plane and on the plane perpendicular to it, *fig. 6*. This is visible within the region of the angle values $\Delta\theta_\perp = \Delta\theta_\parallel = (60\text{–}90)^\circ$. It can be characterized by the ratio m of the proton number $N_{\Delta\theta_\perp}$ in the angle region $\Delta\theta_\perp = (60\text{–}90)^\circ$ to the number $N_{\Delta\theta_\parallel}$ in the same angle region $\Delta\theta_\parallel = (60\text{–}90)^\circ$; this ratio equals:

$$m = N_{\Delta\theta_\parallel}/N_{\Delta\theta_\perp} = 1.15 \pm 0.10. \quad (3)$$

The asymmetry observed and the irregularity appearing in the azimuth and zenith angular distributions of the fast protons indicate the proton emission process to be localized in some definite space region of the bombarded nucleus.

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