ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА

E1-82-802

Z.Strugalski

ASYMMETRIES IN ANGULAR DISTRIBUTIONS OF NUCLEON EMISSION INTENSITY IN HIGH ENERGY HADRON-NUCLEUS COLLISIONS

Submitted to "ЖЭТФ"

1982

1. INTRODUCTION

When a high energy hadron h collides with a massive atomic nucleus of the mass number A, events occur in which the incident hadron is deflected from its original direction of motion with an accompaniment of intensive nucleon emission from the target-nucleus but without particle production: obviously, nuclear fragments f can be emerged as well. Usually, in experiments not all nucleons are registered simply, it is difficult to register effectively the neutrons; protons are observed only and the nucleon emission is characterized by characteristics of its proton component.

We call the kinetic energy E_k of an incident hadron "high", if it is larger than the threshold for the pion production. The term "massive" atomic nucleus we use for nuclei of the mass number $A \geq 10$. As a measure of the nucleon emission intensity in a collision event we use the number n_N of amitted nucleons N, or the number n_p of emitted protons p, when protons are observed only in the experiment.

The emitted nucleons accompanying the collisions are "fast", of kinetic energy from about 20 to about 400 MeV, as we conclude from the energy spectra of the protons observed.

This kind of hadron-nucleus collision events

$$h + A \rightarrow h + n_N + f \qquad (1)$$

could have been discovered when all the secondary pions - electrically charged and neutral, other produced various particles, and the emitted nucleons were registered with an efficiency of about 100%. In practice, any large-size heavy-liquid bubble chamber satisfies such particle registration and detection conditions. We have discovered such kind of events some years ago/1,2/ using 180 litre xenon bubble chamber /3/, and we have investigated their various properties /2,4-7/. In pion-xenon nucleus collisions at 3.5 GeV/c momentum the events in question occur in 9.3±0.5% of all collision events.

When the events without particle production were found, the problem of the asymmetries in nucleon emission intensity angular distributions in hadron-nucleus collisions arose. In fact, in a sample of events of the type (1) the hadron deflection plane, in which the incident hadron and the deflected hadron straight-line courses lie, is naturally distinct plane among

Table 1

Distributions $N(\Delta\phi_p)$ of the proton emission azimuth angles ϕ_p degrees in pion-xenon nucleus collisions without particle production, at 3.5 GeV/c momentum, with multiplicities of emitted protons $n_p \geq 1$ and $n_p \geq 2$ and with incident pions deflected by various angles θ_π degrees; angular sectors $\Delta\phi_p$ are numbered as in fig.1b

№ of sector $\Delta\varphi_p$	$N(\Delta\varphi_p) \pm \Delta N(\Delta\varphi_p)$							
	$n_p \geq 1$					$n_p \geq 2$		
	$\vartheta_\pi \leq 180$	$\vartheta_\pi \leq 60$	$\vartheta_\pi \leq 30$	$\vartheta_\pi > 60$	$\vartheta_\pi > 30$	$\vartheta_\pi \leq 180$	$\vartheta_\pi \leq 60$	$\vartheta_\pi \leq 30$
I	0.109±0.007	0.102±0.008	0.091±0.011	0.124±0.013	0.119±0.009	0.113±0.007	0.108±0.009	0.099±0.013
II	0.116±0.007	0.109±0.008	0.104±0.012	0.133±0.013	0.124±0.009	0.122±0.008	0.117±0.009	0.119±0.014
III	0.120±0.007	0.124±0.009	0.107±0.012	0.110±0.012	0.126±0.009	0.121±0.008	0.127±0.010	0.111±0.013
IV	0.145±0.008	0.136±0.009	0.133±0.013	0.135±0.013	0.138±0.010	0.136±0.008	0.136±0.010	0.134±0.015
V	0.149±0.008	0.157±0.010	0.190±0.016	0.142±0.013	0.128±0.009	0.133±0.008	0.131±0.010	0.141±0.015
VI	0.146±0.008	0.150±0.010	0.161±0.014	0.142±0.014	0.140±0.010	0.148±0.008	0.150±0.010	0.162±0.016
VII	0.109±0.007	0.122±0.009	0.111±0.012	0.107±0.012	0.109±0.008	0.111±0.007	0.114±0.009	0.118±0.014
VIII	0.113±0.007	0.110±0.009	0.103±0.012	0.116±0.012	0.117±0.006	0.109±0.007	0.119±0.010	0.128±0.014

other planes in which incident hadron momentum-vector lies; we call this plane "horizontal" or "hadron-course-plane" and denote it by P_H. Then, various nucleon emission angular characteristics can be studied experimentally relatively to this horizontal plane P_H and relatively to other planes, connected naturally and uniquely with it, and various differences between these characteristics can be discovered; the connected planes we define in the next section. Any asymmetry, if exists, should reflect and characterize a mechanism of the emission of the "fast" nucleons in hadron-nucleus collisions; this mechanism is unknown till now.

The experimental information about the nucleon emission accompanying the hadron-nucleus collisions, used in this work, is mainly from experimental studies of the "fast" proton emission in pion-xenon nucleus collisions /4-7/ of the type (1) performed by means of the 180 litre xenon bubble chamber /3/ exposed to 3.5 GeV/c momentum negatively charged pion beams.

The purpose of this work is to show how asymmetries in nucleon emission intensity angular distributions can be studied experimentally and to obtain some first quantitative characteristics of the asymmetries.

This paper is arranged as follows: after the introduction, in section 1, definitions and terminology are formulated, in section 2; in section 3 appropriate experimental data, reviewed in a form of tables and histograms, are presented; in section 4 results obtained are given; short discussion and remarks close the paper.

2. DEFINITIONS, TERMINOLOGY AND NOTATIONS USED

In considering asymmetries in nucleon emission intensity angular distributions, in hadron-nucleus collisions, various spatial coordinates of points on particle trajectories are in use. It is convenient, therefore, to locate in a definite manner any of the events in a three-dimensional orthogonal coordinate system.

It is known experimentally /6/ that the deflection of a hadron in its passage through atomic nucleus is predominantly a result of multiple collisions of the hadron with constituents of this nucleus and the hadron deflection process develops in space and time; therefore, it is not a naturally distinct definite deflection point on the hadron trajectory. But, we can define the deflection point as the point where the straight-line courses of the hadron before and after the deflection intersect; this point can be identified with an accuracy high enough in experimental studies of the hadron-deflection-events as the center of the "star" where protons forming visible tracks are emitted from, or

Table 2

Dependences of the asymmetries S_{a1} and S_{a2} in proton emission intensity angular distributions on the proton emission azimuth angle ϕ_p. Pion-xenon nucleus collisions were analysed without particle production but with various numbers n_p of emitted protons and with incident pion deflection angles θ_π; asymmetries are defined by formulas (2) and (2′), angles are in degrees

2 a)

Low edge φ_p	$n_p \geq 1$					
	S_{a1}			S_{a2}		
	$\vartheta_\pi \leq 180$	$\vartheta_\pi \leq 60$	$\vartheta_\pi \leq 30$	$\vartheta_\pi \leq 180$	$\vartheta_\pi \leq 60$	$\vartheta_\pi \leq 30$
0	1.00±0.12	1.00±0.16	1.00±0.24	0.95±0.12	0.86±0.13	0.83±0.26
45	1.06±0.13	1.07±0.16	1.14±0.27	1.01±0.12	0.92±0.14	0.85±0.22
90	1.10±0.14	1.22±0.18	1.18±0.27	1.04±0.12	1.05±0.16	0.99±0.22
135	1.33±0.16	1.33±0.19	1.46±0.32	1.26±0.14	1.15±0.10	1.22±0.25
180	1.37±0.16	1.54±0.22	2.10±0.43	1.30±0.14	1.33±0.18	1.83±0.34
225	1.34±0.16	1.47±0.21	1.77±0.37	1.27±0.14	1.27±0.18	1.48±0.29
270	1.00±0.12	1.10±0.17	1.22±0.28	0.95±0.12	0.95±0.15	1.02±0.21
315	1.04±0.12	1.08±0.17	1.13±0.27	0.98±0.12	0.93±0.15	0.94±0.21

2 b)

Low edge φ_p	$n_p \geq 1$					
	S_{a1}			S_{a2}		
	$\vartheta_\pi \geq 0$	$\vartheta_\pi > 30$	$\vartheta_\pi > 60$	$\vartheta_\pi \geq 0$	$\vartheta_\pi > 30$	$\vartheta > 60$
0	1.00±0.12	1.00±0.15	1.00±0.21	0.95±0.12	1.01±0.14	1.14±0.24
45	1.06±0.13	1.04±0.15	1.07±0.22	1.01±0.12	1.05±0.14	1.22±0.24
90	1.10±0.14	1.06±0.15	0.89±0.19	1.04±0.12	1.07±0.14	1.01±0.20
135	1.33±0.16	1.16±0.17	1.09±0.22	1.26±0.14	1.17±0.17	1.24±0.24
180	1.37±0.16	1.08±0.16	1.15±0.22	1.30±0.14	1.09±0.14	1.30±0.24
225	1.34±0.16	1.18±0.17	1.15±0.22	1.27±0.14	1.19±0.17	1.30±0.24
270	1.00±0.12	0.92±0.14	0.86±0.20	0.95±0.12	0.92±0.14	0.98±0.20
315	1.04±0.12	0.98±0.13	0.94±0.19	0.98±0.12	0.99±0.13	1.07±0.20

2 c)

Low edge φ_p	$n_p \geq 2$					
	S_{a1}			S_{a2}		
	$\vartheta_\pi \leq 180$	$\vartheta_\pi \leq 60$	$\vartheta_\pi \leq 30$	$\vartheta_\pi \leq 180$	$\vartheta_\pi \leq 60$	$\vartheta_\pi \leq 30$
0	1.00±0.12	1.00±0.17	1.00±0.26	0.97±0.14	0.90±0.15	0.86±0.21
45	1.08±0.14	1.08±0.17	1.20±0.30	1.05±0.14	0.98±0.15	1.03±0.23
90	1.07±0.14	1.18±0.19	1.12±0.27	1.04±0.14	1.06±0.17	0.97±0.22
135	1.20±0.14	1.26±0.20	1.35±0.33	1.17±0.15	1.13±0.18	1.08±0.24
180	1.18±0.14	1.21±0.20	1.42±0.34	1.15±0.15	1.09±0.18	1.23±0.24
225	1.31±0.15	1.39±0.21	1.64±0.38	1.28±0.15	1.25±0.19	1.41±0.30
270	0.98±0.12	1.06±0.17	1.19±0.30	0.96±0.15	0.95±0.15	1.03±0.23
315	0.96±0.12	1.10±0.17	1.29±0.31	0.94±0.15	0.99±0.15	1.11±0.24

Table 3

Distributions of the proton emission angle vertical projection $\theta^{\pm}_{pV}$ in pion-xenon nucleus collisions without particle production, with a number of emitted protons $n_p \geq 1$, in which incident pion is deflected at an angle θ_π; at 3.5 GeV/c momentum. Angles are in degrees, S_V is defined by formula (3)

Low edge ϑ_{pV}	$n_p \geq 1$ $\vartheta_\pi \leq 180$		
	$N(\vartheta^+_{pV})$	$N(\vartheta^-_{pV})$	S_V
0.0	0.097±0.009	0.092±0.009	0.948±0.181
22.5	0.089±0.009	0.091±0.008	1.022±0.193
45.0	0.081±0.008	0.076±0.008	0.938±0.191
67.5	0.062±0.006	0.065±0.007	1.048±0.214
90.0	0.054±0.006	0.052±0.006	0.963±0.218
112.5	0.044±0.006	0.045±0.006	1.023±0.276
135.0	0.039±0.006	0.040±0.006	1.026±0.312
157.5	0.033±0.006	0.039±0.006	1.182±0.397

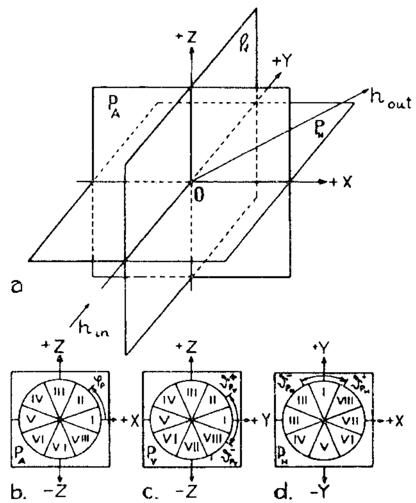


Fig. 1. The location of a hadron-deflection event in the XYZ coordinate system, when asymmetries in angular distributions of the nucleon emission intensities are studied in hadron-nucleus collisions without particle production and with any number of emitted nucleons; h_{in}–0 – incident hadron course before the deflection, 0 – h_{out} – the course of the incident hadron after the deflection, 0 – the deflection point. a. Three naturally distinct planes: P_A – azimuthal plane, P_V – vertical plane, P_H – horizontal plane; b. Definition of the nucleon emission direction azimuth angle ϕ_p, the segments I-VIII are of 45 degrees; c. Definition of the proton emission zenith angle vertical projections $\theta^{\pm}_{pV}$; d. Definition of the proton emission zenith angle horizontal projection $\theta^{\pm}_{pH}$; "+" is for the projections on the horizontal semiplane where the deflected pion lies.

as the point where incident hadron "breaks" – when protons are not observed.

Let us locate the deflection point at the initial point 0 of the orthogonal system XYZ, fig.1, the course of the incident hadron $h_{in}-0$ let us take as the Y axis, the axes X and Z let be situated as in fig.1. Two planes connected naturally with the hadron deflection plane P_H can be distinct: the YZ plane which we call the vertical plane and denote it by P_V, and XZ plane which we call the azimuth plane and denote it by P_A.

For an experimental study of the asymmetry in nucleon emission intensity angular distribution, events of the type (1) in which emitted nucleons are observed are of an interest only. The most convenient variables expressing the state of motion of a nucleon are the energy-momentum four-vector $(E_N, \vec{P}_N c)$ where E_N is the total energy of the nucleon and $\vec{P}_N$ is its momentum. The plane in which the momentum $\vec{P}_N$ of an emitted nucleon and the momentum $\vec{P}_h$ of the incident hadron lie we call, as usually, the nucleon emission plane and denote it by P_N. The angle between the hadron deflection plane, or the horizontal plane P_H, and the nucleon emission plane P_N we call the nucleon emission azimuth angle and denote it by ϕ_N; this angle can change from 0 degrees to 360 degrees, turning left the P_N plane from its "initial" position – when it covers the P_H plane.

The angle between the momentum $\vec{P}_N$ of the emitted nucleon and the incident hadron momentum $\vec{P}_h$ we call the nucleon emission angle, and denote it by θ_N. The projection of the nucleon emission angle θ_N on the horizontal plane P_H we denote by θ_{NH}. We use two indices "+" or "–" in order to distinguish the projections θ^+_{NH} on the +XY-semiplane and the projection θ^-_{NH} on the –XY-semiplane, fig.1d. The projection of θ_N on the vertical plane we denote by θ_{NV} and we use two indices "+" and "–" in order to distinguish between the projection θ^+_{NV} on the +ZY-semiplane and the projection θ^-_{NV} on the –ZY-semiplane, fig.1c. The nucleon emission angle projection θ^+_{NV} and θ^+_{NH} can change from 0 to 180 degrees, the θ^-_{NV} and θ^-_{NH} can change from 0 to 180 degrees as well. Usually, as it has been remarked above, events are studied in which protons are observed only; in these cases the index "p" should be used instead of the index "N".

Three possible asymmetries can be distinguished in nucleon emission intensity angular distributions in the hadron-nucleus collision events of the type (1):

1. The azimuthal asymmetry, which we define as

$$S_{a1} = \frac{N(\phi_p \pm \Delta\phi_p)}{N(\phi_p = 0 \pm \Delta\phi_p)} \qquad (2)$$

Table 4

Distributions of the proton emission zenith angle horizontal projection θ^{+-}_{pH} in pion-xenon nucleus collision events at 3.5 GeV/c momentum without particle production, with a number $n_p \geq 1$ of emitted protons, in which incident hadron is deflected by various angles θ_π; angles are in degrees

Low edge ϑ^{+-}_{pH}	$\vartheta_\pi \leq 180$: $N(\vartheta^+_{pH})$	$\vartheta_\pi \leq 180$: $N(\vartheta^-_{pH})$	$\vartheta_\pi \leq 60$: $N(\vartheta^+_{pH})$	$\vartheta_\pi \leq 60$: $N(\vartheta^-_{pH})$	$\vartheta_\pi > 60$: $N(\vartheta^+_{pH})$	$\vartheta_\pi > 60$: $N(\vartheta^-_{pH})$
0.0	0.080±0.008	0.098±0.009	0.083±0.010	0.102±0.012	0.074±0.015	0.090±0.016
22.5	0.073±0.008	0.089±0.009	0.069±0.010	0.084±0.011	0.084±0.016	0.099±0.017
45.0	0.072±0.008	0.107±0.010	0.069±0.010	0.112±0.012	0.080±0.015	0.097±0.016
67.5	0.050±0.006	0.083±0.008	0.047±0.008	0.091±0.011	0.058±0.014	0.066±0.014
90.0	0.044±0.006	0.059±0.007	0.040±0.007	0.064±0.009	0.048±0.012	0.050±0.010
112.5	0.044±0.006	0.051±0.006	0.040±0.007	0.050±0.008	0.053±0.012	0.053±0.012
135.0	0.039±0.006	0.038±0.006	0.039±0.007	0.035±0.007	0.040±0.010	0.043±0.009
157.5	0.033±0.005	0.038±0.006	0.033±0.007	0.041±0.007	0.033±0.009	0.031±0.009

Table 5

Distributions of the proton emission zenith angle horizontal projection θ_{pH}^{+-} in pion-xenon nucleus collision events at 3.5 GeV/c momentum without particle production, with $n_p \geq 2$ protons emitted, and with incident pion deflected by various angles θ_π; angles are in degrees

Low edge ϑ_{pH}^{+-}	$\vartheta_\pi \leqslant 180$		$\vartheta_\pi \leqslant 30$		$\vartheta_\pi > 30$	
	$N(\vartheta_{pH}^{+})$	$N(\vartheta_{pH}^{-})$	$N(\vartheta_{pH}^{+})$	$N(\vartheta_{pH}^{-})$	$N(\vartheta_{pH}^{+})$	$N(\vartheta_{pH}^{-})$
0.0	0.082 ± 0.009	0.098 ± 0.009	0.087 ± 0.016	0.104 ± 0.016	0.080 ± 0.010	0.096 ± 0.010
22.5	0.076 ± 0.008	0.089 ± 0.009	0.067 ± 0.014	0.074 ± 0.014	0.079 ± 0.010	0.094 ± 0.010
45.0	0.074 ± 0.008	0.096 ± 0.010	0.056 ± 0.013	0.106 ± 0.016	0.082 ± 0.010	0.092 ± 0.010
67.5	0.053 ± 0.007	0.077 ± 0.008	0.045 ± 0.011	0.090 ± 0.016	0.056 ± 0.008	0.070 ± 0.009
90.0	0.046 ± 0.006	0.057 ± 0.008	0.051 ± 0.012	0.061 ± 0.012	0.045 ± 0.008	0.056 ± 0.009
112.5	0.047 ± 0.006	0.051 ± 0.006	0.050 ± 0.012	0.053 ± 0.012	0.045 ± 0.008	0.051 ± 0.008
135.0	0.039 ± 0.006	0.039 ± 0.006	0.040 ± 0.011	0.034 ± 0.010	0.039 ± 0.008	0.041 ± 0.008
157.0	0.036 ± 0.005	0.041 ± 0.006	0.035 ± 0.011	0.047 ± 0.012	0.035 ± 0.008	0.040 ± 0.008

or

$$S_{a2} = \frac{N(\phi_p \pm \Delta\phi_p)}{\frac{1}{2}\{N(\phi_p = 90 \pm \Delta\phi_p) + N(\phi_p = 270 \pm \Delta\phi_p)\}}, \qquad (2')$$

where $N(\phi_p \pm \Delta\phi_p)$ are the numbers of protons within an angular interval $\Delta\phi_p$ at ϕ_p; it is convenient to use $\Delta\phi_p = 22.5$ degrees at the values of the ϕ_p = 0, 45, 90, 135, 180, 225, 270, 315, 360 degrees.

2. The zenithal asymmetry in the vertical plane P_V, or zenith vertical asymmetry, which we define as

$$S_V = \frac{N(\theta_{NV}^{-}, \Delta\theta_{NV}^{-})}{N(\theta_{NV}^{+}, \Delta\theta_{NV}^{+})}, \qquad (3)$$

where $N(\theta_{NV}^{+-}, \Delta\theta_{NV}^{+-})$ are numbers of events within the projection interval $\Delta\theta_{NV}^{+-}$ at a projection angle θ_{NV}^{+-}; it is convenient to use $\Delta\theta_{NV}^{+-} = 22.5$ degrees at $\theta_{NV}^{+-} = 0$, ± 22.5, ± 45, ± 67.5, ± 90, ± 112.5, ± 135, ± 157.5 degrees.

3. The zenithal asymmetry in the horizontal plane P_H, or zenith horizontal asymmetry, which we define as

$$S_H = \frac{N(\theta_{NH}^{+}, \Delta\theta_{NH}^{+})}{N(\theta_{NH}^{-}, \Delta\theta_{NH}^{-})}, \qquad (4)$$

where $N(\theta_{NH}^{+-}, \Delta\theta_{NH}^{+-})$ are the numbers of nucleons, or protons, within an angular interval $\Delta\theta_{NH}^{+-}$ at a projection angle θ_{NH}^{+-}; it is convenient to use $\Delta\theta_{NH}^{+-} = 22.5$ degrees at $\theta_{NH}^{+-} = 0$, ± 22.5, ± 45, ± 67.5, ± 90, ± 112.5, ± 135, ± 157.5 degrees.

3. EXPERIMENTAL DATA

In this section experimental data characterizing asymmetries (2)-(4) are presented and analysed in a special manner, just adequately for the proton emission asymmetry quantitative description. The data are obtained in analysing the sample of 876 pion-xenon nucleus collision events, at 3.5 GeV/c momentum, without particle production, of the type (1); this sample of events was already a subject matter in a preliminary experimental study of the proton emission intensity angular distributions in our work with T.Pawlak and J.Pluta.

The events of the type (1) were recognized in the scanning; the scanning efficiency was about 100% when the pion deflection angle was larger than 2 degrees, in events with $n_p = 0$, and when this angle was larger than 0 or almost equal to 0, in events with $n_p \geq 1$. In any of the events the proton emission zenith angle θ_p, azimuth angle ϕ_p, and the pion deflection angle were

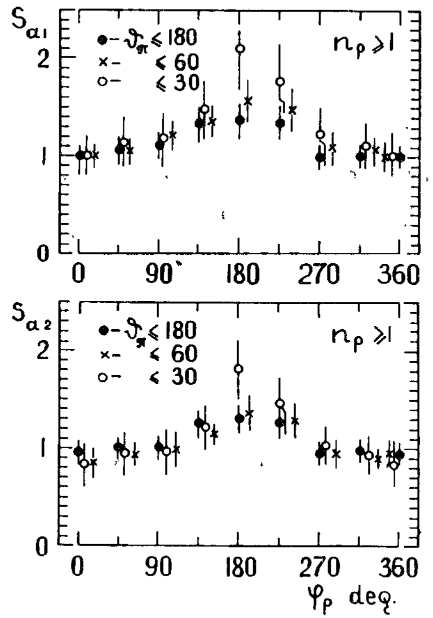


Fig.2. Dependences of the quantities S_{a1} and S_{a2},defined by formulas (2) and (2′) describing the proton emission azimuthal asymmetry, on the azimuth angle ϕ_p. Pion-xenon nucleus collisions are used at 3.5 GeV/c momentum in which particles are not produced and any number n_p of emitted protons is observed.

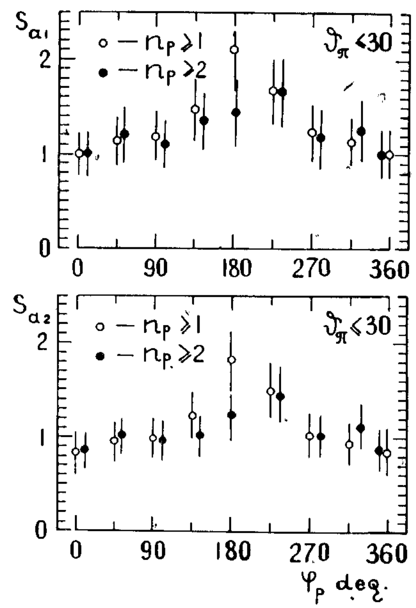


Fig.3. Dependences of the quantities S_{a1} and S_{a2}, defined by formulas (2) and (2′), on the proton emission azimuth angle ϕ_p, in pion-xenon nucleus collisions at 3.5 GeV/c momentum without particle production and with numbers n_p of emitted protons $n_p \geq 1$ and $n_p \geq 2$, in classes of events with incident pion deflection angles $\theta_\pi \leq 30$ degrees.

measured; the accuracy of the proton emission angle is, in average, 3 degrees, the accuracy of the pion deflection angle is about 1 degree. The kinetic energy of any of the protons emitted was estimated, using range-energy relation [8], with an average accuracy of about 4%.

Values of the θ_{pV}^{+-} and of the θ_{pH}^{+-} were estimated in experiment using formulas:

$$\theta_{pV}^{+-} = \mathrm{arc\ tg}\ \beta^{+-}, \qquad (5)$$

Fig.4. Dependences of the quantities S_{a1} and S_{a2}, defined by formulas (2) and (2′), on the proton emission azimuth angle ϕ_p, in pion-xenon nucleus collisions at 3.5 GeV/c momentum without particle production, in classes of events when the incident pion is deflected by various angles θ_π and any number of emitted protons $n_p \geq 1$ is observed.

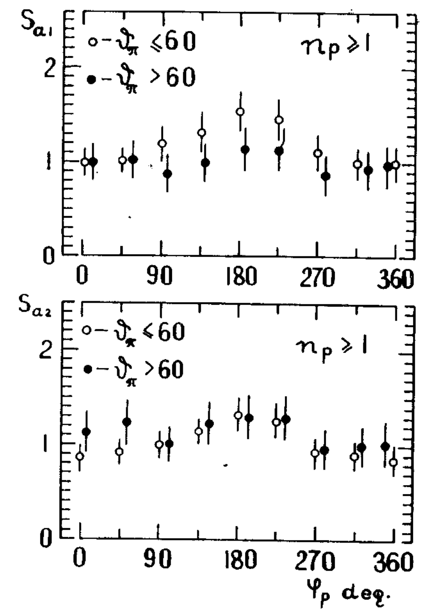


Fig.5. Dependence of the quantity S_V describing the "vertical zenith asymmetry" in proton emission, defined by formula (3), on the proton emission angle vertical projection θ_{pV}^{+-}. In pion-xenon nucleus collisions without particle production, at 3.5 GeV/c momentum,with the number of emitted protons $n_p \geq 1$ and with any incident pion deflection angle $\theta_\pi \leq 180$ degrees.

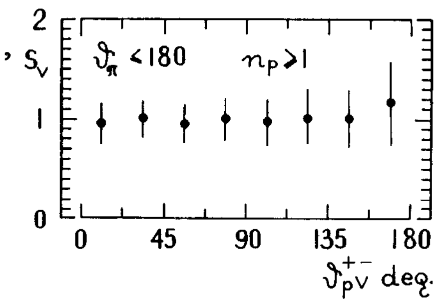
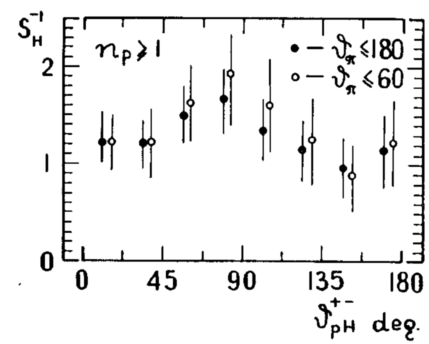


Fig.6. Dependence of the quantity S_H describing proton emission "horizontal" asymmetry, defined by formula (4), on the proton emission zenith angle horizontal projection θ_{pH}^{+-}. In pion-xenon nucleus collisions without particle production, at 3.5 GeV/c momentum, in which a number $n_p \geq 1$ of emitted protons occur and the incident pion is deflected by various deflection angles θ_π.



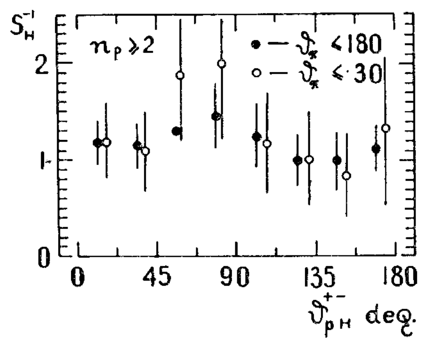


Fig.7. Dependences of the quantity S_H describing proton emission "horizontal" asymmetry, defined by formula (4), on the proton emission zenith angle horizontal projection θ^{+-}_{pH}. Pion-xenon nucleus collisions without particle production, at 3.5 GeV/c momentum, in which $n_p \geq 2$ protons are emitted and incident pion is deflected by various deflection angles θ_π.

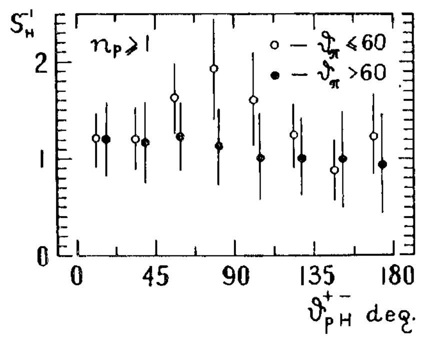


Fig.8. Dependences of the quantity S_H describing proton emission "horizontal" asymmetry, defined by formula (4), on the proton emission zenith angle horizontal projection θ^{+-}_{pH}. Pion-xenon nucleus collisions without particle production, at 3.5 GeV/c momentum, in which $n_p \geq 1$ protons are emitted and the incident pion is deflected by any angle θ_π.

where $\mathrm{tg}\,\beta^{+-} = P^{+-}_{py}/P^{+-}_{ph}$ and P^{+-}_{py} are the positive- or negative-sign projections of the proton momentum P_p on the axis perpendicular to the hadron deflection plane, P^{+-}_{ph} are the proton momentum $\vec{P}_p$ negative or positive components on the hadron course;

$$\theta^{+-}_{pH} = \mathrm{arc\ tg}\,\alpha^{+-}, \qquad (6)$$

where $\mathrm{tg}\,\alpha^{+-} = P^{+-}_{px}/P^{+-}_{ph}$ and P^{+-}_{px} are the positive or the negative components of the proton momentum $\vec{P}_p$ on the axis perpendicular to the incident hadron course, lying in the hadron deflection plane.

The quantities defined in section 2, describing the asymmetry, are presented in tables 1-5 and in figs.2-8.

In order to eliminate a possible influence of the kinematical properties of the proton emission in events of the type $\pi^- + p \to \pi^- + p$ on the proton emission intensity angular distribution in events of the type (1) with $n_p \geq 1$, we prepare the experimental characteristics of the proton emission intensity angular distributions for two classes of events of the type (1) separately - when $n_p \geq 1$ and when $n_p \geq 2$; fig.3, fig.5 and fig.6.

4. RESULTS AND REMARKS

Short review of the data presented above allow us to conclude that:

1) The azimuth asymmetry defined by formulas (2) and (2′) as S_{a1} and S_{a2} exists in both the classes of events of the type (1), when the multiplicity of the emitted protons is $n_p \geq 1$ and $n_p \geq 2$; it is shown in tables 2a)-2c) and in figs.2 and 3.

2) The intensity of the proton emission is maximum at the azimuth angle $\phi_p \approx 180$ degrees, fig.1a and 1b, and fig.2 and fig.3.

3) The zenith asymmetry S_V in angular distribution of the proton emission intensity, defined by formula (3), does not exist, fig.5; $S_V \approx 1$ within θ^{+-}_{pV} angle intervals from 0 to ± 180 degrees, fig.1a and 1c, and fig.5.

4) The zenithal asymmetry S_H, defined by formula (4), exists in angular distribution of the proton emission intensity, fig.6 and fig.7. The maximum value of the quantity S_H corresponds to the zenith angle $\theta^-_{pH} \approx -80$ degrees, fig.1a and 1d, and figs.6 and 7.

We have presented above the existence of asymmetries in angular distributions of the proton emission intensity in special class of pion-xenon nucleus collisions, of the type (1), at relatively small momentum of incident pions. It is reasonable to think that the events of this kind occur and may be observed when any of hadrons of the kinetic energy higher than the pion production threshold collides with are atomic nucleus of the mass number A larget enough. In all such cases the existence of asymmetries in proton emission intensity angular distributions will be certainly detected. We do not find an argumentation that the asymmetry in proton emission intensity angular distributions is not a general property of the proton emission process accompanying the hadron passage through nuclear matter. But, in hadron-nucleus collisions with many produced particles in the final state the asymmetries are practically unobservable, if simple methods of the analysis of the hadron-nucleus collision process are applied.

In analysing relations between the multiplicity $n_{\pi^{\pm}_0}$ of produced pions and the average multiplicity of emitted protons $<n_p>$ and of neutral "stars" observed $<n_n>$, in all-type pion-xenon nucleus collision events at 3.5 GeV/c momentum, we found that the shapes of the $n_{\pi^{\pm}_0} - <n_p>$ and $n_{\pi^{\pm}_0} - <n_n>$ dependences are almost identical. It forces us to state that the asymmetries discovered in the proton emission intensity angular distributions are proper to the neutron emission as well.

REFERENCES

1. Strugalski Z., Pluta J. Journ.of Nucl.Phys. (Russian), 1974, 27, p.504.
2. Strugalski Z. et al. JINR, E1-11975, Dubna, 1978.
3. Kuznetsov E.V. et al. Instr. and Exp.Technique, 1970, 2, p.56.
4. Strugalski Z. et al. JINR, E1-82-718, Dubna, 1982.
5. Strugalski Z., Pawlak T., Pluta J. JINR, E1-82-285, Dubna, 1982.
6. Strugalski Z. JINR, E1-82-455, Dubna, 1982.
7. Strugalski Z., Pawlak T., Pluta J. JINR, E1-82-719, Dubna, 1982.
8. Kanarek T., Strugalski Z. JINR, 1-3320, Dubna, 1967.

Received by Publishing Department
on November 25, 1982.

SUBJECT CATEGORIES OF THE JINR PUBLICATIONS

Index	Subject
1.	High energy experimental physics
2.	High energy theoretical physics
3.	Low energy experimental physics
4.	Low energy theoretical physics
5.	Mathematics
6.	Nuclear spectroscopy and radiochemistry
7.	Heavy ion physics
8.	Cryogenics
9.	Accelerators
10.	Automatization of data processing
11.	Computing mathematics and technique
12.	Chemistry
13.	Experimental techniques and methods
14.	Solid state physics. Liquids
15.	Experimental physics of nuclear reactions at low energies
16.	Health physics. Shieldings
17.	Theory of condenced matter
18.	Applied researches
19.	Biophysics

Стругальский З. E1-82-802

Асимметрии в угловых распределениях интенсивности испускания нуклонов в адрон-ядро столкновениях при высоких энергиях

Обильно встречаются такие случаи адрон-ядро столкновений при высоких энергиях, в которых налетающий адрон, проникая через массивное ядро-мишень, подвергается лишь отклонению в сопровождении интенсивного испускания нуклонов из ядра, но без рождения частиц. При использовании соответствующих экспериментальных данных по пион-ксенон ядерным столкновениям при импульсе 3,5 ГэВ/с исследуется асимметрия в угловых распределениях интенсивности испускания нуклонов относительно плоскости отклонения налетающего адрона и относительно двух однозначно с ней сопряженных вертикальных к ней плоскостей. Приводятся количественные характеристики обнаруженных асимметрий.

Работа выполнены в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1982

Strugalski Z. E1-82-802

Asymmetries in Angular Distributions of Nucleon Emission Intensity in High Energy Hadron-Nucleus Collisions

High energy hadron-nucleus collision events occur plentifully in which incident hadron is deflected only in its passage through the massive target-nucleus in accompaniment of intensive emission of nucleons from the target, but without particle production. Asymmetry in nucleon emission intensity angular distributions relatively to the hadron deflection plane and to two planes normal to it and related to it uniquely is analyzed, using appropriate experimental data on pion-xenon nucleus collisions at 3.5 GeV/c momentum. Quantitative characteristics of the asymmetries found are presented in tables and on figures.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1982