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INTENSITY OF THE NEUTRON EMISSION FROM NUCLEI, INDUCED BY HIGH ENERGY HADRONIC PROJECTILES

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1. INTRODUCTION

The subject matter of this work is to present experimental characteristics of the neutron emission from nuclei, induced by high energy hadronic projectiles. This paper is a sequel to the author's last paper: Neutron emission from target nuclei, induced by high energy hadronic projectiles/1/. It is based on the newly obtained experimental data from the 180 litre xenon bubble chamber/2/, exposed to 3.5 GeV/c momentum negatively charged pion beam/3/ from the accelerator of the Moscow Institute of Theoretical and Experimental Physics.

2. EXPERIMENTAL PROCEDURE

Neutrons are registered in the bubble chamber by means of "neutral stars" recorded on photographs; in the 180 litre chamber the registration efficiency/1/ is about 28%.

For a simplicity, in the analysis of the events recorded on the stereophotographs, the single hadron-xenon nucleus collision event photographs were analysed only. The pictures selected in such a manner were clear and without background from other collision events inside the chamber. The neutrons emitted in the hadron-xenon nucleus collision reactions cause characteristic "neutral stars" in collisions of the neutrons with the downstream xenon nuclei - observed protons are emitted from the nuclear targets radially; the proton tracks form the "stars".

Information about the experimental procedure, and especially about the photograph scanning and measurements on the selected pictures can be found in our former works/1,4/ and in the papers cited in them.

The neutron emission intensity we determine as the number n_n of the emitted neutrons, or as the neutron emission multiplicity n_n.

3. EXPERIMENTAL DATA

About 40000 photographs were scanned and rescanned. 1128 single event pictures were recorded on them. The number n_p, or multiplicity n_p, of the tracks caused by the protons emitted in neutron-xenon collision reactions are from $n_p = 1$ up to $n_p = 7$; the "stars" were observed with n_p prongs therefore.

3.1. The Background Neutral Stars

On the chamber photographs, there are recorded not only the stars produced by the neutrons emitted in the collision reactions of the incident hadrons with the xenon nuclei inside the chamber. Some of stars are produced by other neutrons - from other various sources, from some kind of reactions outside the chamber. Such stars form the background against which the neutral stars which we are looking for are registered.

In order to take into account the background neutral stars per one picture, 2237 chamber pictures were singled out on which no any collision reaction of the beam hadrons with the xenon nuclei inside the chamber were registered. In this sample of photographs, 294 were found on which neutral stars are recorded; in total, 379 such neutral stars are seen on them - we call them the background stars later. And so, the percentage of the background stars on the photographs is $k = 379/2237 = 16.9\pm0.2\%$ per a photograph.

3.2. Characteristics of the Neutral Stars

The characteristics of neutral stars are presented in Tables 1÷5. The data presented in Table 1 are based on the sample of 684 pion-xenon nucleus collision events; in total 2341 protons and 3339 neutrons are emitted in them. The neutron registration efficiency[1] is taken into account. The ratio between the number of the emitted protons and of the emitted neutrons, in the total sample of events, is 0.70; it is as large as the ratio $Z/(A-Z)$, where $A = 131$ and $Z = 54$ are the mass and charge numbers of the Xe nucleus.

The distribution of the neutral stars with various numbers of the emitted protons in them is characterized in Table 2. In about 95% of the stars, the pion-xenon nucleus collision reactions at 3.5 GeV/c momentum are accompanied by, multiplicity of the emitted protons is no more than $n_p = 3$. The proton multiplicity distribution in the background neutral stars is similar, Table 3. The distribution of the proton multiplicities in the neutral stars when the background stars are taken into account is shown in Table 4.

The background neutral stars could be recorded when the multiplicity n_p of the emitted protons at least equals to 1. Let

us suppose then that the photographs without the background neutral stars are in fact the photographs with the 0 prong neutral stars. Then, instead of the n_p distribution presented in Table 3, the proton multiplicity n_p distribution in the background neutral stars will be as presented in Table 5. In the light of such interpretation, the relatively significant number of the background neutral stars is when $n_p < 3$, Table 5.

Table 1. General information about the intensity of the neutron emission from target nuclei, in pion-xenon nuclear collisions at 3.5 GeV/c momentum. Designations: n_p - the number of protons emitted in a collision event, N_{ev} - number of collision events with a given n_p, $N_{n\ obs}$ - the number of neutrons observed in collisions with a given n_p, $N_{n\ cor}$ - the number of neutrons in all collisions with a given n_p after correction for the neutron registration efficiency, $< n_n >$/event - mean multiplicity of the emitted neutrons per collision event with a given n_p, $< n_N >$/event - number of nucleons emitted per event with a given n_p, $< n_N > = < n_n > + < n_p >$. *the value obtained by extrapolation

n_p	N_{ev}	$N_{n\ obs}$	$N_{n\ cor}$	$<n_n>$/event	$<n_N>$/event
0	122	185	557	5.4*	5.4*
1	98	172	518	5.3	6.3
2	81	142	428	5.3	7.3
3	76	123	370	4.9	7.9
4	78	129	388	5.1	9.1
5	70	106	319	4.6	9.6
6	48	72	217	4.5	10.5
7	45	73	220	4.9	11.9
8	36	56	169	4.7	12.7
9	12	18	52	4.3	13.3
10	11	21	63	5.8	15.8
11	4	10	30	7.5	18.5
12	1	1	3	3.0	15.0
13	2	2	6	6.0	19.0

Table 2. Characteristics of the neutral stars registered in the 180 litre xenon bubble chamber exposed to negatively charged pion beam at 3.5 GeV/c momentum. Denotations: n_p - the number of protons emitted in the star or the number of star prongs, N_{ev} - number of the pion-xenon nuclear collision events with n_p-prong stars, N_n - the number of the neutral stars, $N_{ev}(n_p)$ - the percentage of the n_p-prong stars

n_p	N_{ev}	$N_n \pm \Delta N_n$	$N_{ev}(n_p)$ %
1	695	1036 ± 33	61.6
2	269	401 18	23.9
3	90	134 10	8.0
4	49	73 9	4.3
5	16	24 4	1.4
6	7	10 3	
7	2	3 1	

Table 3. Prong multiplicity n_p distribution $N_n(n_p)$ in the background neutral stars; N_n - the number of the neutral stars with the n_p prongs

n_p	N_n	$N_n(n_p)$ %
1	305	80.5
2	63	16.6
3	5	1.3
4	4	1.1
5	1	0.3
6	1	0.3

4. DISCUSSION AND RESULTS

On the basis of experimental data presented above, it may be concluded that:

1. The mean number $< n_n >$ of the neutrons emitted in pion-xenon nucleus collisions at 3.5 GeV/c momentum is almost constant - it does not depend on the multiplicity n_p of the emitted protons in the collisions; $< n_n > \approx 5.1 \pm 0.9$ neutrons.

2. The ratio between the number of the emitted protons Σn_p and of the emitted neutrons Σn_n in total sample of the pion-

Table 4. Prong multiplicity distribution in neutral stars which the pion-xenon nuclear collisions at 3.5 GeV/c mimentum are accompanied by; the background stars are taken into account. Denotations: n_p - the prong multiplicity, N_n - the number of the neutral stars, $N_n(n_p)$ % - the percentage of the stars with a given number n_p of prongs

n_p	$N_n \pm \Delta N_n$	$N_n(n_p)$ %
1	807 33	57.7
2	354 18	25.3
3	130 10	9.3
4	70 9	5.0
5	23 4	1.6
6	10 3	0.7
7	3 1	0.2

Table 5. The distribution $N_n(n_p)$ of the background neutral stars with various numbers n_p of the protons emitted in them

n_p	N_n	$N_n(n_p)$ %
1	1858	83.1
2	305	13.6
3	63	2.8
4	5	0.2
5	4	0.2
6	1	0.1
7	1	0.1

xenon nucleus collisions is $\Sigma n_p / \Sigma n_n = Z/(A-Z)$, where A and Z are the mass and charge numbers of the xenon nuclei.

3. The mean numbers $< n_N > = < n_p > + < n_n >$ of the nucleons emitted in the pion-xenon nucleus collisions at 3.5 GeV/c momentum is $< n_N > = 8.3 \pm 0.9$; the value of the $< n_p >$ is from our former work [5]. Corresponding value of $< n_N >$ expected in our calculations [6] is $< n_N > = 8.52$. It is just as large as the value 8.3±0.9 obtained here experimentally. This agreement means that the number of nucleons emitted in hadron-nucleus collisions equals the number of nucleons met by the projectile

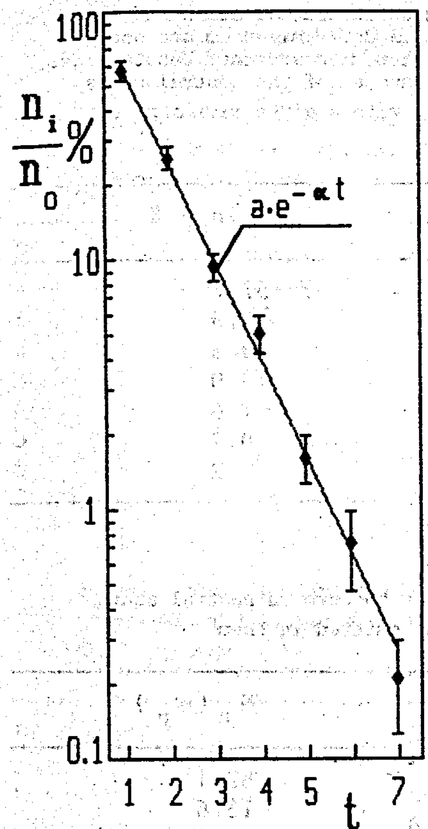

Fig.1. The percentage n_{n_i}/n_0 % distribution for neutral stars with various numbers t of prongs, in pion-xenon nucleus collisions at 3.5 GeV/c momentum. n_{n_i} - number of stars with n_i prongs, n_0 - total number of neutral stars in the sample under investigation. The line superimposed on the experimental distribution is fitted to the experimental points, with the parameters a = 158, $\alpha = 0.92 \pm 0.02$, $\chi^2 = 10.6$, ndf = 5.

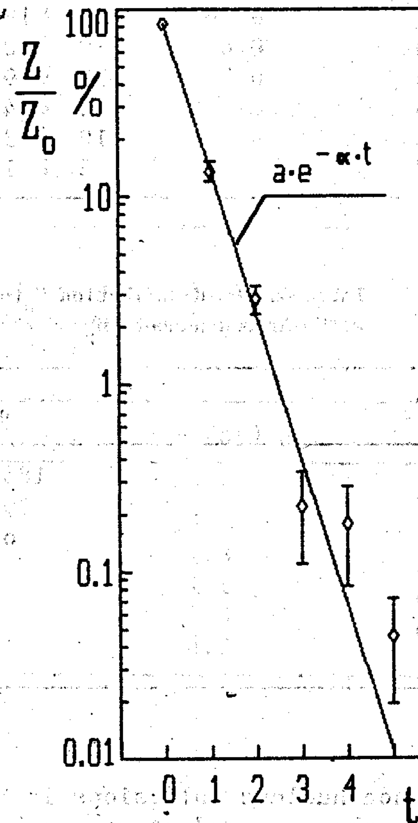

Fig.2. The percentage Z/Z_0 % distributions for the background neutral stars with various numbers t of prongs. Z - the number of stars with a given prong number t, Z_0 - the total number of stars in the sample under study. The parameters for the fitting line are: a = = 78.7, $\alpha = +1.83 \pm 0.4$, $\chi^2 = 144$, ndf = 4.

hadron around its course in the intranuclear matter at the distance as the nuclear force range is[5,6,7].

4. The prong multiplicity distribution in the background neutral stars differs markedly from the distribution in the neutral stars produced by neutrons emitted in the pion-xenon nucleus collisions under the investigation, Tables 2-5, and figs.1 and 2.

5. The information about the dependence $\langle n_N \rangle$/event on the multiplicity n_p of the emitted protons in the pion-xenon nucleus collisions at 3.5 GeV/c momentum contains the data on the matter density distribution inside the target nuclei[8].

6. The prong multiplicity n_p distribution $N(n_p)$ in the neutral stars, the pion-xenon nucleus collisions are accompanied by, can be described by simple formula $a \cdot e^{-\alpha n_p}$, where a = = 158, $\alpha = +0.92 \pm 0.02$, $\chi^2 = 10.6$, ndf = 5, fig.1.

Shortly, we are in the position to state that: the neutron emission from target nuclei, induced by high energy hadronic projectiles proceeds according to the laws known[5,7] for the proton emission.

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