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FRAGMENTATION PARAMETERS OF COSMIC-RAY NUCLEI IN NUCLEAR PHOTOEMULSION

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The work presented has been carried out upon experimental material obtained by the irradiation of emulsion on the satellite Intercosmos-6. It deals with the determination of fragmentation parameters have been determined on a large statistical set, especially for light and heavy nuclei of the photoemulsion. The energy of the incident nuclei is higher then 2 GeV/nucl. The comparison of our results with those published by other authors is given in the conclusion.

ПАРАМЕТРЫ ФРАГМЕНТАЦИИ ЯДЕР КОСМИЧЕСКИХ ЛУЧЕЙ В ЯДЕРНЫХ ФОТОЭМУЛЬСИЯХ

В работе приведены экспериментальные данные, полученные при облучении эмульсий на спутнике «Интеркосмос-6». При этом определялись параметры фрагментации тяжелых ядер с зарядом $Z \geq 10$. Параметры фрагментации определены на больших статистических наборах, главным образом для легких и тяжелых ядер фотоэмульсии. Энергия падающих ядер больше, чем 2 ГэВ/нуклон. В конце статьи сравниваются полученные результаты с данными других авторов.

I. INTRODUCTION

In our work we attempt to determine more precisely the fragmentation parameters of heavy nuclei of the cosmic ray with a charge $Z \geq 10$ in nuclear photoemulsion. By the fragmentation of a nucleus we understand a process of fission of the incident nucleus i on the target nucleus y by producing the new nucleus j, which moves in the same direction, with the same energy per nucleon as that in nucleus i and with a charge lower or the same as the charge of the incident nucleus $Zj \leq Zi$. The fragmentation parameter Pij gives the number of fragments of the type j produced in the process of fragmentation of the nucleus i, i.e., the probability of fission of the nucleus i into the nucleus j during an inelastic nucleus-nucleus interaction.

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The experimental material for the study of inelastic collisions of high energy particles of the primary cosmic ray with nuclei of the photoemulsion has been obtained from the experiment on the Earth satellite Intercosmos-6.

One part of the experimental equipment was also a block of the photoemulsion NIKFI BR-2 with a capacity of 45 l. A more detailed description of the satellite orbit parameters, experimental equipment on its board and of the further treatment of the emulsion block can be found in [1] and [4].

II. DESCRIPTION OF THE EXPERIMENTAL TREATMENT

The detection of primary cosmic radiation trajectories in nuclear photoemulsion with dimensions: $10\times20\times0.045$ cm^3 has been carried out at the distance of 0.5 cm from the edge of the emulsion through which the particle entered the emulsion, by means of a ZEISS-AMPLIVAL microscope with the eyepiece 12.5× and a lens 6.3×. We selected only those trajectories which satisfy the following criteria:

a) The length of the trajectory in one emulsion plate is greater than 0.7 cm (at the given magnification it was equal to three visual fields in the microscope).

b) The trajectory of the primary particle at the given magnification must be clearly visible, which corresponds to the particles with a charge of $Z\geq10$.

By means of these criteria we speeded up the detection and evaluation of the individual trajectories. Totally, 2784 out of the heavy nuclei trajectories of primary cosmic radiation satisfied these criteria and more than 240 m of nuclear photoemulsion was scanned simultaneously. The scanning of the trajectories, which have satisfied the given conditions was carried out by the same microscope with a lens 16.5×. In the case of some changes on the trajectory of the nucleus, or in the case of an inelastic collision, an immersed lens with a 100× magnification was used. All the fragments resulting from the interaction were scanned using the same magnification until their exit from the emulsion, or until further interaction. As heavy fragments only nuclei with a charge $Z\leq3$ were considered, alpha-particles were not scanned further. As fragments of a nucleus we considered only those high-energy nuclei, the direction change of which was in comparison to the incident nucleus less than 3° in the laboratory system.

The charge of all primary nuclei and fragments was determined by the summation method of slow δ-electrons, described in [4].

In the determination of the charge by this method the error is $|\Delta Z|\leq1$.

III. FRAGMENTATION PARAMETERS

Fragmentation parameters *Pij* of nuclei of the cosmic ray photoemulsion have been calculated from the 708 observed interactions (630 primary and 78 secondary

Table 1

Mean values	Primary interactions	Secondary interactions
Z	15.5±1.7	11.5±1.2
N_h	9.6±0.7	6.1±0.5
n_s	11.4±0.8	8.8±0.6

N_h — number of black tracks
n_s — number of relativistic tracks

Table 2

Z_j \ Z_i	LM	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
α LM	27	25	26	111	75	199	75	181	88	208	44	63	2	20	5	3	–	10
10	–	1	–	3	2	5	2	4	1	1	–	–	–	–	–	–	–	–
11			–	1	3	4	1	9	2	3	–	–	–	1	–	–	–	–
12				1	3	6	3	14	3	3	1	2	–	1	–	–	–	–
13					1	3	3	4	1	3	–	1	–	–	–	–	–	–
14						1	5	10	4	13	3	–	–	–	–	1	–	–
15							3	1	3	6	–	4	–	–	–	–	–	–
16								–	–	6	2	2	–	–	–	–	–	1
17									1	1	3	–	–	1	–	–	–	–
18										1	1	1	–	–	–	–	–	–
19											–	–	–	1	–	–	–	–
20												–	–	1	–	–	–	–
21													–	–	–	–	–	1
22														–	–	–	–	1
23															–	–	–	–
24																–	–	–
25																	–	–
26																		–
Σ	26	20	24	79	44	133	53	115	42	97	25	27	1	12	1	3	–	6
Σ	26	353						279				50						

*LM: $3\leq Z\leq9$

Table 5

N_h	Kažimír, Just Σi	P_{ij}	Σj	Freier, Waddington Σi	P_{ij}	Σj	Judek, Heerden Σi	P_{ij}	Σj
LM→αLM	26	1.038±0.200	27	613	0.887±0.038	544	466	0.861±0.043	401
H3→αLM		1.448±0.064	511		1.464±0.081	328		1.482±0.132	126
	353		224				85		
→H3		0.144±0.020	51		0.161±0.027	36		0.153±0.042	13
H2→αLM		1.867±0.082	521		1.924±0.116	277		1.500±0.261	33
→H3	279	0.319±0.034	89	144	0.306±0.046	44	22	0.227±0.102	5
→H2		0.054±0.014	15		0.063±0.021	9		0.091±0.064	2
H1→αLM		2.060±0.203	103		2.158±0.044	2365		2.133±0.218	96
→H3		0.200±0.063	10		0.179±0.013	196		0.044±0.031	2
	50			1096			45		
→H2		0.120±0.049	6		0.151±0.012	165		0.289±0.080	13
→H1		0.060±0.036	3		0.109±0.010	120		0.133±0.054	6

Table 6

$N_h \leq 7$	Kažimír, Just Σi	P_{ij}	Σj	Judek, Heerden Σi	P_{ij}	Σj
LM → αLM	16	1.250±0.280	20	283	1.113±0.063	315
H3 → LM		1.724±0.092	350		1.683±0.163	106
	203			63		
→ H3		0.192±0.031	39		0.190±0.055	12
H2 → αLM		1.993±0.118	285		1.363±0.352	15
→ H3	143	0.448±0.056	64	11	0.273±0.160	3
→ H2		0.070±0.022	10		0.091	3
H1 → αLM		2.348±0.319	54		1.880±0.274	47
→ H3		0.231±0.094	6		0.080±0.056	2
	23			25		
→ H2		0.192±0.082	5		0.360±0.120	9
→		0.115±0.067	3		0.200±0.089	5

According to Tables 5, 6, 7 it is clear that the observed fragmentation parameters are in very good accordance with the fragmentation parameters given in the work [2] and in good agreement with [3], in the whole charge interval within the limit of errors.

Table 7

$N_h > 7$	Kažimír, Just Σi	P_{ij}	Σj	Judek, Heerden Σi	P_{ij}	Σj
LM → αLM	10	0.700±0.265	7	183	0.470±0.051	86
H3 → LM		1.073±0.085	161		0.909±0.203	20
	150			22		
→ H3		0.080±0.023	12		0.045	1
H2 → LM		1.735±0.113	236		1.636±0.386	18
→ H3	136	0.184±0.037	25	11	0.182±0.129	2
→ H2		0.037±0.017	5		0.091	1
H1 → αLM		1.815±0.259	49		2.450±0.350	49
± H3		0.148±0.074	4		—	—
	27			20		
→ H2		0.37	1		0.200±0.100	4
→ H1		—	—		0.050	1

IV. DISCUSSION

1) On a large statistical set fragmentation parameters of primary cosmic radiation in photoemulsion have been determined. This set is one of the largest hitherto evaluated sets of nucleus-nucleus collisions.

2) Our results are in good accordance with the works of other authors. The comparison was made for particles with any energy of about 2 GeV per nucleon. The difference is observed only in the fragmentation into alpha-particles, which were not determined by a suitable method.

3) We determined the fragmentation parameters for individual nuclei in group H2, which has not been published yet.

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