ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

ДУБНА

E2 - 9089

V.K.Lukyanov, Yu.A.Panebratsev, A.I.Titov

FRAGMENTATION OF RELATIVISTIC HEAVY IONS

1975

E2 - 9089

V.K.Lukyanov, Yu.A.Panebratsev, A.I.Titov

FRAGMENTATION OF RELATIVISTIC HEAVY IONS

Submitted to "Письма в ЖЭТФ"

Лукьянов В.К., Панебратцев Ю.А., Титов А.И. **E2 - 9089**

Фрагментация релятивистских тяжелых ионов

Дано объяснение недавних экспериментов по выходам фрагментов в реакциях с релятивистскими тяжелыми ионами на основе двухстадийного механизма процесса: на первой стадии ион возбуждается в результате периферийного столкновения с ядром-мишенью, на второй распадается статистически на лету с выходом фрагмента.

Работа выполнена в Лаборатории теоретической физики ОИЯИ.

Препринт Объединенного института ядерных исследований
Дубна 1975

E2 - 9089

Lukyanov V.K., Panebratsev Yu.A., Titov A.I.

Fragmentation of Relativistic Heavy Ions

Recent experiments on the fragment yields in the reactions with relativistic heavy ions are explained on the basis of a two-stage mechanism of the process: at the first stage an ion is excited by the preripheral collision with a nucleus-target, at the second one it decays in flight with the fragment yield.

The investigation has been performed at the Laboratory of Theoretical Physics, JINR.

Preprint of the Joint Institute for Nuclear Research
Dubna 1975

The first experiment of fragmentation of the relativistic oxygen ions on the beryllium target /1/ caused the appearance of some models for mechanism of such a reaction /2-6/. All these have the nature of a preliminary search and require further development to be tested experimentally. Thus, in addition to the problem on the momentum distribution of fragments, raised in all the papers, the best criterion for the choice of mechanism is the explanation of the product yield of the reaction /6/. While in /1/ the data on yields are not presented, in the recent paper /7/ the problem on yields has specially been investigated experimentally. The yields were measured for fast fragments with the mean velocity equal to the corresponding velocity of an incident ion in collisions of the relativistic ions of ^{16}O (E =2.1, 1.05 GeV/n) and ^{12}C (E = 2.1 GeV/n) which strike onto different targets from hydrogen to lead. The results have been found to be of the form

$$\sigma = \gamma_B^F (A_T^{1/3} + A_B^{1/3} - 1.6). \qquad (1)$$

It is just the representation in which the dependence of fragmentation on the atomic number of a target A_T and of a projectile A_B turns out to be distinguished. The factors γ_B^F characterize the essential dependence on Z and A of a detected fragment yields and, in practice, do not depend on the projectile energy.

In this note the attempts are made to explain the observed yields of fragments γ_B^F on the basic of the following assumption on the mechanism /6/ . The reaction proceeds in two stages: at the first stage the ion is excited up to energy E^* due to the collision with the nucleus-target, at the second one there occurs its statistical decay in flight with the fragment yield of energy ϵ . Then the distribution of fragments obeys the ratio of phase volumes in the final state

$$W(i)d\epsilon = \frac{\rho_f(E^*-\epsilon+Q_{gg})}{\rho_c(E^*)}\epsilon d\epsilon \sim C(\epsilon)e^{\frac{Q_{gg}(i)}{T}}, \qquad (2)$$

where ρ is the state density resp., before (c) anf after (f) statistical decay, and $Q_{gg} = M_{ion} - M_{fr} - M_r(i)$ is the reaction energy released in the disintegration channel i with the yield of the fragment of M_{fr} and of the other products of masses $M_r(i)$, $T = \sqrt{2E^*/a}$ is the temperature of the ion excitation (a smallness of $(\epsilon - Q_{gg})$ as compared to the ion excitation energy E^* is assumed). Since in experiment only one reaction product, the fragment with mass M_{fr} , is registered and not the others with $M_r(i)$ the observed total yield is $\gamma_B^F = \sum_i \gamma_B^F(i)$, where $\gamma_B^F(i)$ is the yield in a channel i . Then it is convenient to represent the data in the form

$$\gamma_B^F(i) = \gamma_B^F \Gamma(i), \qquad (3)$$

where

$$\Gamma(i) = W(i)/\sum_i W(i) \qquad (4)$$

characterizes the channel width. The figure shows the calculation results for γ_B^F by formulae (3), (4). Circles stand for values of (3), the numbers inside them denote the corresponding channels written in the Table. One can see the following: 1). The yields really obey the exponential Q_{gg} dependence that, in its turn, justifies the mechanism of statistical decay of ion in the beam frame (if the process is nonequilibrium, T has the meaning of the effective temperature, see refs. /6,8/). From the slope of the curve one determines $T = 7.5$ MeV for ^{12}C ion and $T = 7.0$ MeV for ^{16}O . The small decrease in T for the heavier ion is natural. 2). An additional test of this mechanism could be the experiments on coincidence with registration of the heavy and light fragments with the momenta per nucleon close to the corresponding moments of the incident ion. 3).In the presented model there remains the question on the first-stage mechanism: how the large excitation energy $E^* \gtrsim 50$ MeV can be transferred to ion and why the observed distribu-

Table

		^{16}O - ^{A}Z+ ...				^{12}C - ^{A}Z+ ...	
^{A}Z	i	channel	-Q(MeV)	^{A}Z	i	channel	-Q(MeV)
^{15}O	1	^{15}O+n	15,7	^{11}C	1	^{11}C+n	18,7
^{14}O	1	^{14}O+2n	28,9	^{10}C	1	^{10}C+2n	31,9
^{13}O	1	^{13}O+3n	52,1	^{9}C	1	^{9}C+3n	53,1
^{15}N	1	^{15}N+p	12,1	^{11}B	1	^{11}B+p	16,0
^{14}N	1	^{14}N+^{2}H	20,7	^{10}B	1	^{10}B+^{2}H	25,2
	2	^{14}N+n+p	23,0		2	^{10}B+n+p	27,4
^{13}N	1	^{13}N+^{3}H	25,0	^{8}B	1	^{8}B+^{3}H+n	45,9
	2	^{13}N+^{2}H+n	31,3		2	^{8}B+^{4}H	48,9
	3	^{13}N+2n+p	33,5		3	^{8}B+^{2}H+2n	52,2
^{12}N	1	^{12}N+^{3}H+n	45,1		4	^{8}B+3n+p	54,4
	2	^{12}N+^{4}H	48,0	^{10}Be		^{10}Be+2p	27,2
	3	^{12}N+^{2}H+2n	51,4	^{9}Be	1	^{9}Be+^{3}He	26,3
	4	^{12}N+3n+p	53,6		2	^{9}Be+^{2}H+p	31,8
^{14}C		^{14}C+2p	22,3		3	^{9}Be+n+2p	34,0
^{13}C	1	^{13}C+^{3}He	22,8	^{7}Be	1	^{7}Be+^{4}He+n	26,3
	2	^{13}C+^{2}H+p	28,3		2	^{7}Be+^{5}He	27,2
	3	^{13}C+n+2p	30,5		3	^{7}Be+^{3}H+^{2}H	43,9
^{12}C		^{12}C+^{4}He	7,2		4	^{7}Be+^{3}H+n+p	46,1
^{11}C	1	^{11}C+^{4}He+n	25,9		5	^{7}Be+^{3}He+2n	46,9
	2	^{11}C+^{5}He	26,8	^{9}Li		^{9}Li+3p	46,8
	3	^{11}C+^{3}H+^{2}H	43,5	^{8}Li	1	^{8}Li+^{3}He+p	43,2
^{10}C	1	^{10}C+^{6}He	38,0		2	^{8}Li+^{9}Li	46,1
	2	^{10}C+^{4}He+2n	39,0		3	^{8}Li+^{2}H+2p	48,7
	3	^{10}C+^{5}He+n	39,9		4	^{8}Li+3p+n	50,9

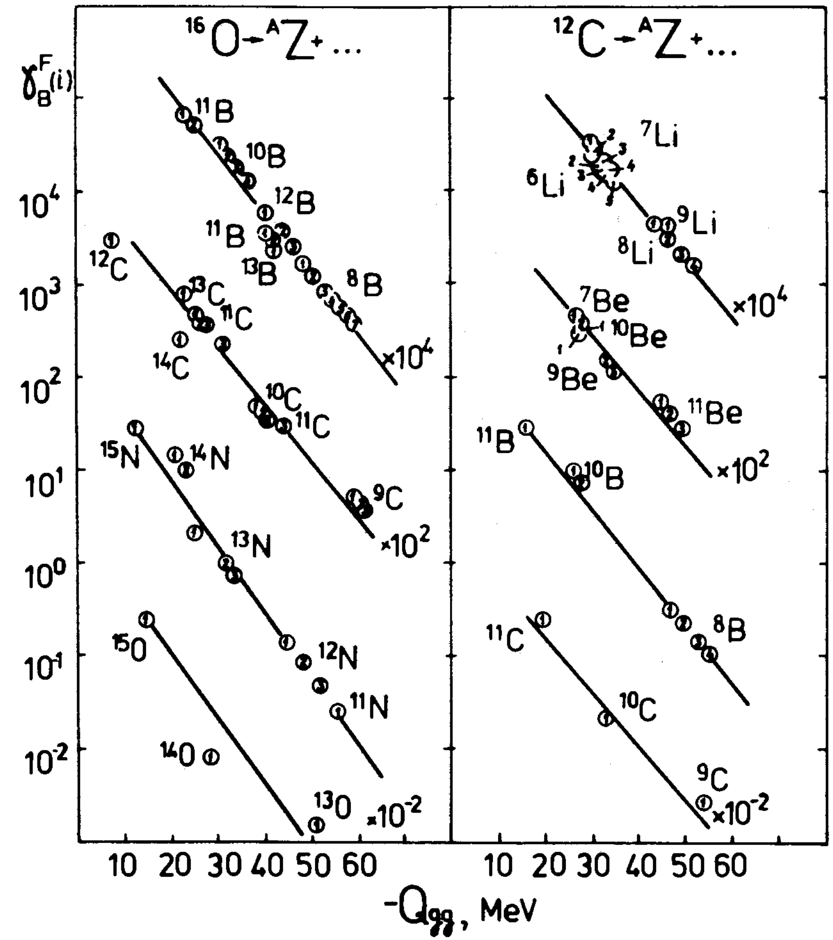
^{9}C	1	^{9}C+^{6}He+n	59.3	^{7}Li	1	^{7}Li+^{4}He+p	24,6
	2	^{9}C+^{4}He+3n	60.3		2	^{7}Li+^{5}Li	26,6
	3	^{9}C+^{5}He+2n	61.2		3	^{7}Li+^{3}H+2p	44,4
^{13}B		^{13}B+3p	43.1		4	^{7}Li+^{3}He+n+p	45,2
^{12}B	1	^{12}B+^{3}He+p	40.3	^{6}Li	1	^{6}Li+^{6}Li	28.2
	2	^{12}B+^{4}Li	43.2		2	^{6}Li+^{4}He+^{2}H	29,7
	3	^{12}B+^{2}H+2p	45,8		3	^{6}Li+^{4}He+n+p	31.9
^{11}B	1	^{11}B+^{4}He+p	23,1		4	^{6}Li+^{5}He+p	32.8
	2	^{11}B+^{5}Li	25.1		5	^{6}Li+^{5}Li+n	33,8
	3	^{11}B+^{3}He+^{2}H	41.5				
	4	^{11}B+^{3}H+2p	42.9				
^{10}B	1	^{10}B+^{6}Li	30.9				
	2	^{10}B+^{4}He+^{2}H	32.4				
	3	^{10}B+^{4}He+n+p	34.6				
	4	^{10}B+^{5}Li+n	36.5				
^{8}B	1	^{8}B+^{8}Li	48.6				
	2	^{8}B+^{7}Li+n	50.6				
	3	^{8}B+^{4}He+^{3}H+n	53,11				
	4	^{8}B+^{5}He+^{3}H	54.0				
	5	^{8}B+^{4}He+^{4}H	56.0				

tions over momenta have almost equal widths for all fragments. Thus, if the first stage proceeds according to the direct reaction mechanism it should be expected that the width will change as follows: $\approx\sqrt{2A_{fr}(A_B-A_{fr})E_{fr}}$ with changing separation energy of fragment in the incident ion.

REFERENCES

1. H.H.Heckman et al. Proc. Fifth Int. Conf. on HEPNS in Uppsala, 1973.
2. H.Feshbach, K.Huang. Phys.Lett., 47B, 300 (1973).
3. J.V.Lepore, R.J.Riddell. LBL-3086 (1974).
4. R.K.Bhadury. Phys.Lett., 50B, 211 (1974).
5. A.M.Baldin. Investigations with Relativistic Nuclei, Lectures in MIPI, Moscow, 1975.
6. V.K.Lukyanov, A.I.Titov. Phys.Lett., 57B, 11 (1975).
7. P.J.Lindstrom,D.F.Greiner, H.H.Heckman, B.Cork, F.S.Bieser. LBL-3650 (1975).
8. K.K.Gudima, A.S.Iljinov, V.D.Toneev. Preprint JINR, P7-7915, Dubna, 1974.

Received by Publishing Department on July 23, 1975.



The relative yields of fragments versus the Q_{gg} -reaction.