УДК 539.126.34+539.172.16+539.172.17

INCLUSIVE SPECTRA OF PROTONS AND π^- MESONS EMITTED IN ^{4}HeC AND ^{12}CC INTERACTIONS WITH TOTAL DISINTEGRATION OF NUCLEI

M.K.Suleimanov[1]*, *O.B.Abdinov*[1], *A.I.Anoshin*[2], *J.Bogdanowicz*[3], *A.A.Kuznetsov*

The invariant inclusive spectra of protons and π^- mesons as a function of their kinetic energies (T) in the laboratory system of coordinates for ^{4}HeC and ^{12}CC interactions at a momentum of 4.2 A GeV/c with a different number of protons (Q) are used. The spectra are fitted by expressions of the form $\sum_{i=1}^{n} = a_i \exp(-b_i T)$ and the Q-dependences of the inverses of slopes ($T_i = 1/b_i$) are studied. It is found that these spectra have two components (a low-energy component corresponds to T_1; and a high-energy component, to T_2) and contain the regime change points. For protons, the first component is mainly connected with evaporation protons, and leading-stripping fragments have a great influence on T_2. In the region of total disintegration of nuclei, the leading-stripping effect is suppressed, and the values of T_i for π^- mesons begin to increase with increasing Q.

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

Инклюзивные спектры протонов и π^--мезонов, испущенных в ^{4}HeC- и ^{12}CC-взаимодействиях с полным развалом ядер

М.К.Сулейманов и др.

Использованы инвариантные инклюзивные спектры протонов и π^--мезонов как функция их кинетических энергий T в лабораторной системе координат для ^{4}HeC- и ^{12}CC-взаимодействий при импульсах 4,2 А ГэВ/с с разными значениями протонов — Q. Спектры аппроксимировались выражениями вида $\sum_{i=1}^{n} = a_i \exp(-b_i T)$, и изучались зависимости значений обратных наклонов $T_i = 1/b_i$ от величин Q. Получено, что эти спектры имеют две компоненты — низкоэнергичную компоненту, соответствующую T_1, и высокоэнергичную компоненту, соответствующую T_2, и содержат точки смены режимов для ^{4}HeC-взаимодействий при значениях $Q \geq 2$ и 4, а для ^{12}CC-взаимодействий при значениях $Q \geq 6$ и 9. Для протонов первая компонента в основном связана с испарительными протонами, а на значения T_2 большое влияние оказывают лидирующие-стриппинговые

[1]Physics Institute, Azerbaijan Academy of Sciences, Baku, Azerbaijan Republic
[2]Nuclear Physics Institute, Moscow State University, Moscow, Russia
[3]Soltan Institute for Nuclear Studies, Warsaw, Poland and Joint Institute for Nuclear Research, Dubna,Russia
*Now at the Laboratory of High Energies, JINR, 141980 Dubna, Russia, E-mail: mais@sunhe.jinr.ru

фрагменты. В области полного развала ядра происходит подавление лидирующего-стриппингового эффекта, а значения T_i для π^--мезонов начинают расти с увеличением Q.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Introduction

In this paper we discuss the experimental results of studying the invariant inclusive spectra $f = (E/\sigma)d^3\sigma/dp^3$ of protons and π^- mesons as a function of their kinetic energies in the laboratory system of coordinates. The spectra $f(T)$ were obtained for ^{4}HeC and ^{12}CC interactions at a momentum of 4.2 A GeV/c with a different number of protons (Q) emitted from the nucleus.

It is known that (see, for example, [1]) the spectra $f(T)$ are exponential in form with a good accuracy. Therefore, we fitted these spectra by an expression of the form

$$\sum_{i=1}^{n} a_i \exp(-b_i T) \qquad (1)$$

(here a_i and b_i are the fitting parameters, the quantity n is determined from the condition of the best fitting: the errors in determining a_i and b_i and the values of χ^2 per degree of freedom are minimum) and studied the dependence of $T_i = 1/b_i$ on variable Q.

The use of T_i as a primary variable is connected with that this quantity can be presented as a sum of energies corresponding to the system «temperature» (T_0) and the energy due to the system motion itself. One can expect that the motion energy will tend to zero in the region of large Q. Therefore, the values of T_i will become close to T_0 when passing to the processes of the disintegration of nuclei in the region of large Q.

2. Experimental Details

In this paper the experimental data were obtained by exposing the 2 m propane bubble chamber of LHE JINR to the beams of light relativistic nuclei at the Dubna Synchrophasotron at a momentum of 4.2 A GeV/c. The chamber was placed in a magnetic field of 1.5 T. The statistics are 4852 ^{4}HeC and 7327 ^{12}CC interactions (for methodical details see [2]). We had the 4π geometry for measurement and detected practically all secondary particles. However, it should be noted that protons in our experiment are identified by ionization and their range over a momentum interval of 0.15—0.50 GeV/c. The range of protons with momenta $p < 0.15$ GeV/c is smaller than 2 mm, and most of them are not seen in a photo. For all positive particles with momenta higher than 0.5 GeV/c, we introduced the weight that determined the probability for the particle to be a proton or a π^+meson. The characteristics of the π^+ meson were used to determine the weights. The smallest momentum for the detection of mesons was 0.07 GeV/c. The contamination by electrons and negative strange particles did not exceed 5% and 1%, respectively.

In this paper, the variable Q is used to determine the number of protons. We defined Q for each event as

$$Q = N_+ - N_{\pi^-}, \tag{2}$$

where N_+ is the number of positive particles and N_{π^-} is the number of π^- mesons (we assumed $N_{\pi^+} = N_{\pi^-}$). It should be noted that the experimental losses of particles and the errors in identifying secondary particles and fragments affect the accuracy of determining the values of Q. A bad accuracy in determining Q can result in the appearance of «false» Q^* and extension of the regions of regime changes. For this reason, we cannot determine precisely the number of regime change regions and the values of Q^* corresponding to them. To decrease the influence of this factor, we consider not the groups of events with definite values of Q but the groups of events with Q larger than a certain value, i.e., the integral spectrum. Under such an assumption, the influence of accidents of all kinds decreases. Therefore, the experimental material was divided into groups of events with the following values of Q:

$$Q \geq 1; 2; 3; 4; 5; 6; 7$$

for ^{4}HeC interactions and

$$Q \geq 1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11$$

for ^{12}CC interactions, and the spectra of $f(T)$ were obtained for each group of events.

3. Main Results

The spectra of $f(T)$ for ^{12}CC with $Q \geq 1; 3; 6; 9$ are shown in Figs. 1(*a,b*) (solid lines demonstrate the results of the best fitting). One can see that these spectra have an exponential form. The spectra obtained at other values of Q and the spectra for ^{4}HeC interactions have a similar form. Therefore, all the spectra were fitted by expression (1).

It turned out that $n = 2$ in all the considered cases (the values of χ^2 per degree of freedom are given in the Table), i.e., these spectra have two components: a low-energy component corresponding to T_1 and a high-energy component corresponding to T_2. This result is a well-known experimental fact (see, for example, [1] and references therein) interpreted as an indication of the presence of two sources (or mechanisms) of emission of the observed particles.

Table. The values of χ^2 per degree of freedom

Q	^{4}HeC		^{12}CC	
	π^-	p	π^-	p
1	1.17	2.64	0.61	2.29
2	0.60	2.45	0.56	2.18
3	1.33	2.10	0.64	1.94
4	0.90	2.33	0.64	1.70
5	0.73	2.01	0.73	1.44
6	0.47	0.93	0.58	1.22
7	0.81	1.02	0.54	0.92
8	—	—	0.55	1.72
9	—	—	0.39	1.35
10	—	—	0.61	1.65
11	—	—	0.56	1.54

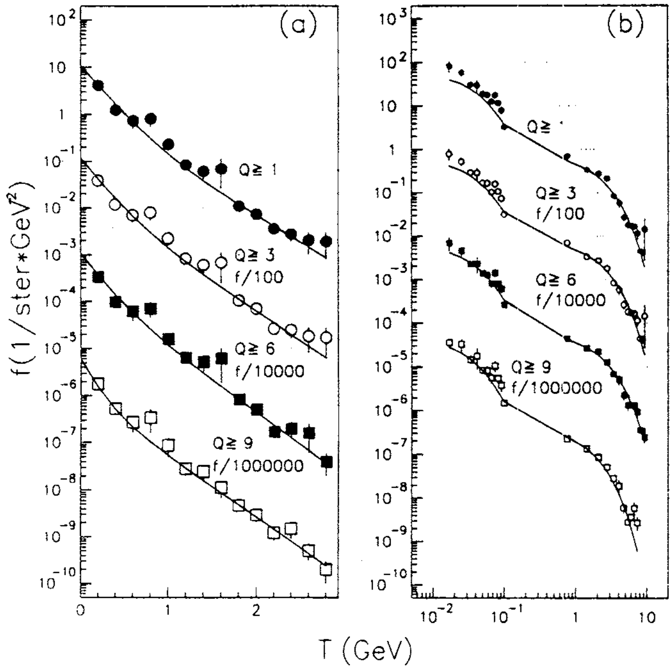

Fig.1. T-dependence of invariant inclusive spectra for π^- mesons (a) and protons (b) emitted in ^{12}CC interactions. Solid lines are the fitting results. The data are given for events with $Q \geq 1$, $Q \geq 3$ (the corresponding values of $f(T)$ are divided by 100), $Q \geq 6$ (the corresponding values of $f(T)$ are divided by 10000), $Q \geq 9$ (the corresponding values of $f(T)$ are divided by 1000000)

The Q-dependence of T_i is shown in Figs.2(a,b) and 3(a,b). It is seen that for protons:

— The values of T_1 (Fig.2a) reach 30 MeV at a maximum and decrease weakly with growing projectile mass. This result agrees with the conclusion [1] that a low-energy part of the proton spectrum is mainly due to evaporation protons. The decrease of T_1 with growing Q is due to increasing energy losses for secondary interactions;

— The values of T_2 (Fig.2b) increase sharply with growing projectile mass.

The regime change points (or region) are observed at $Q \geq 4$ and 6 for ^{4}HeC interac-

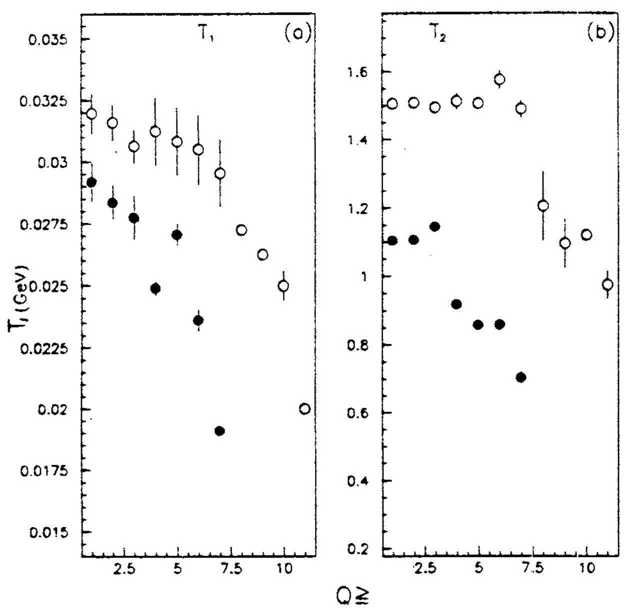

Fig.2. Q-dependence of T_1 (a) and T_2 (b) for protons emitted in ^{4}HeC (•) and ^{12}CC (o) interactions

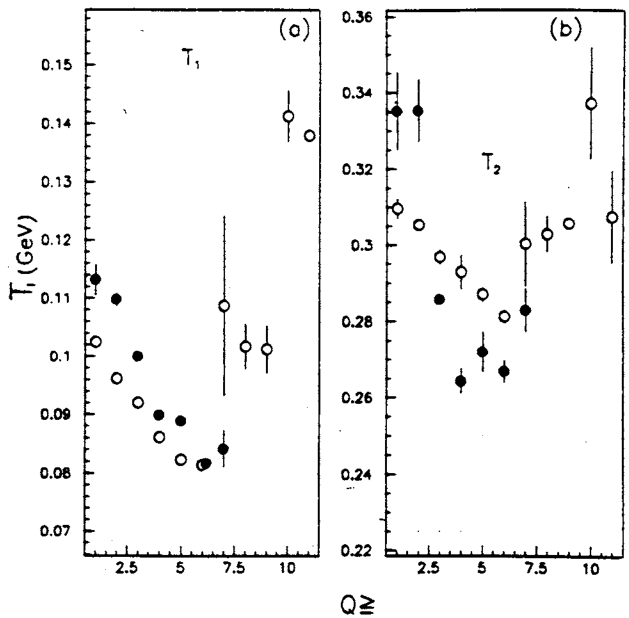

Fig.3. Q-dependence of T_1 (*a*) and T_2 (*b*) for π^- mesons emitted in ^{4}HeC (•) and ^{12}CC (o) interactions

tions and $Q \geq 8$ for ^{12}CC. This result is in good agreement with the conclusions of [3], where similar regime change points were found from the analysis of the probability of the Q distributions of events and the dependences of the mean characteristics of events on Q. In Refs.3, the values of Q corresponding to the regime change points were regarded as «critical» ones (Q^*) and used to select events with total disintegration of nuclei $Q \geq Q^*$. Note that the values of T_2 for protons are almost independent of Q in the region $Q \geq Q^*$ and they decrease sharply in the region $Q \geq Q^*$. We think that this is connected with the admixture of leading-stripping fragments among the considered protons. In the region of large Q, the leading-stripping effect is suppressed. Against the background of this effect, it is difficult to get information on the internal energy (and thus on T_0) of nuclear matter since the difference between the values of T_0 and leading-stripping particle energy is very large.

From the data in Fig.3(*a,b*), it is seen that:

— The spectra of secondary π^- mesons are also well fitted by the expression $\sum_{i=1}^{n} a_i \exp(-b_i T)$ with $n = 2$ (i.e., there are two sources (mechanisms) of π^- mesons emission) and contain regime change points for ^{4}HeC interactions at $Q \geq 2$ and 4 (Fig.3*b*) and for ^{12}CC at $Q \geq 6$ and 9 (see Fig.3*a*).

— At the beginning of these spectra, the values of T_i decrease with increasing Q to Q^* and reach a minimum; then, as Q increases in the $Q \geq Q^*$ region, T_i stops decreasing for ^{4}HeC interactions and increases sharply for ^{12}CC. It is interesting to note that T_1 and T_2 depend on Q in a similar way.

So, we have obtained that the character of Q-dependence of T_i for π^- mesons and protons (T_2) in ^{4}HeC and ^{12}CC collisions changes transitting to the region of total disintegration of nuclei — the region with $Q \geq Q^*$. In this region, the values of T_2 for protons decrease and the values of T_i for π^- mesons increase with increasing Q. One of the possible reasons of the latter can be the appearance of high «temperature» states of nuclear matter in the processes with total disintegration of nuclei.

Acknowledgements

The authors would like to thank the staff of the 2 m propane bubble chamber for giving the experimental material and Academician A.M.Baldin for his permanent attention to the work.

This work was supported by Grant INTAS-96-0678.

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Received on September 14, 1998.