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Multiplicity and angular distributions of particles, produced in central collisions between ^{12}C ions and emulsion nuclei were studied at momentum 4.2 GeV/c per incident nucleon. The investigated data represent the most central collisions which had ever been studied yet. Events of central collisions are defined, here, as those having no projectile charged fragments, even a single charged one, emitted within 3° of the beam direction. The analysis of the experimental data shows agreement with the limiting fragmentation hypothesis. The multiple production of particles in central collisions is not in disagreement with the assumption of a superposition of nucleon-nucleon collisions. The angular distributions of target fragmentation particles, grey and black particle tracks corresponding to proton kinetic energy $27 < T \leq 400$ and $T \leq 27$ MeV respectively, do not show statistically significant peak which would have been attributed to a collective "shock wave" phenomenon. The longitudinal velocity of the emitting system, found from black tracks analysis, is low and typically equals 0.014 ± 0.002 .

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1. - INTRODUCTION

High energy reactions between nuclei are classically divided into peripheral and central collisions. Peripheral interactions usually occur when the impact parameter b nearly equals the sum of projectile and target nuclei radii. These reactions are associated with low momentum and/or energy transfer, consequently they have a small number of generated particles and emitted target fragments. The projectile fragments usually fly in a narrow forward cone with momentum per nucleon equals to that of a projectile nucleon. In this class of events, there will be target and projectile spectators, in addition to nucleons which participate in the initial energy and momentum transfer. These nucleons are called participants. The spectator nuclei are supposed to disintegrate through a fragmentation or an evaporation process. In the peripheral interactions, the rapidity distribution is mainly consisted of projectile and target fragmentation regions which are separable at relativistic energies.

The interaction is central when the impact parameter is less than the absolute value of the difference between the interacting nuclei radii i.e. $b < |R_P - R_T|$, where R_P and R_T are the projectile and target nucleus radii respectively. Such events are characterized by large multiplicities of the generated particles and the emitted target fragments. The emission of particles is symmetric with respect to the direction of the incident beam. In central collisions all projectile nucleons are participants and no projectile spectators. When a nucleon no longer is a spectator but participates in the reaction, it is scattered into the rapidity space between the projectile and target fragmentation regions. Therefore in central reactions, $b < |R_P - R_T|$, the whole kinematically-allowed rapidity space is available for the generated particles. When $R_P < R_T$ the rapidity space, available for the particles is almost limited to the interval between the projectile and target fragmentation regions.

The interest for studying central collisions between heavy ions and nuclei has increased recently. This interest is due to the possibility that in a transient state of such collisions nuclear matter may become compressed to more than its normal density and new phenomena such as for example high density isomers and shock waves can appear. These possibilities are widely discussed in many theoretical and experimental activities⁽¹⁻²⁰⁾. In ref. (12) the author indicated that in central collisions of ^{12}C ions with Ag emulsion nuclei at 4.2 GeV/nucleon, the nuclear density in the interaction zone is about four times its normal value. He assumed a nuclear fireball model to describe such abnormal density state⁽²¹⁾. The proposed model implies that nuclear matter, in this case behaves as if it were one gigantic fireball carrying a large baryon charge which decays later into baryons and pions. Of particular importance is the paper⁽¹⁰⁾ in which the authors suggested that future heavy ion experiments should be focused on central collisions to obtain the pion multiplicity distribution at nearly zero impact parameter $b \approx 0$. In their theoretical analysis, they have shown that for various models, if there are no strong correlations between the generated pions, the Poisson multiplicity distribution is expected at a fixed impact parameter collisions.

Nuclear emulsions are adequate for studying central collisions, due to their high spatial resolution and the possibility of investigating event-by-event in a 4π geometry.

2. - EXPERIMENT

Stacks of $600\ \mu\text{m}$ thick Br-2 nuclear emulsions were exposed to the 4.2 GeV/c per incident nucleon ^{12}C beam at the Dubna Synchrophasotron. Only very thick dark beam tracks, apart from the surface and bottom by at least $50\ \mu\text{m}$ (undeveloped emulsion), were chosen for along the track double scanning, fast in the forward and slow in the backward direction. Thus, we raised the scanning efficiency nearly to 100% and picked up mostly all events having the difference between the charges of the projectile and the principal projectile fragment $\Delta Z = Z_P - Z_F < 2$ which could escape detection in case of forward scanning only. Also, we minimized as much as possible the scanning of beam tracks of $Z_P \leq 5$ light nuclei. However, the scanned beam tracks were further examined by

measuring the δ -electron density on each of them. The negligible fraction of beam particles having $Z \leq 5$ were thus identified and excluded from our data^(16,22,23). The one-prong events, with an emission angle of secondary particle track $\theta < 3^\circ$ and without visible tracks from excitation or disintegration of the incident particle and/or target nucleus, were excluded as due to elastic scattering.

Along the total scanned length of 337.9 m, 2468 inelastic interactions of ^{12}C ions with emulsion were recorded, leading to the mean free path for inelastic interaction $\lambda = 13.7 \pm 0.3$ cm. We studied the mean free path values for ^2H , ^4He and ^{12}C at energy 4.2 GeV/nucleon in ref. (22) and it was found that the formula of Bradt-Peters⁽²⁴⁾ is consistent with the experimental data. In ref. (25) the authors have analysed the collisions of 2.1 GeV/nucleon ^4He , ^{12}C , ^{14}N and ^{16}O with emulsion. They found that the "soft spheres" model⁽¹¹⁾ can predict the values of the cross sections. Fig. 1 is a plot of $1/\lambda$ against $A_p^{2/3}$ for our results and others from refs. (25,26),

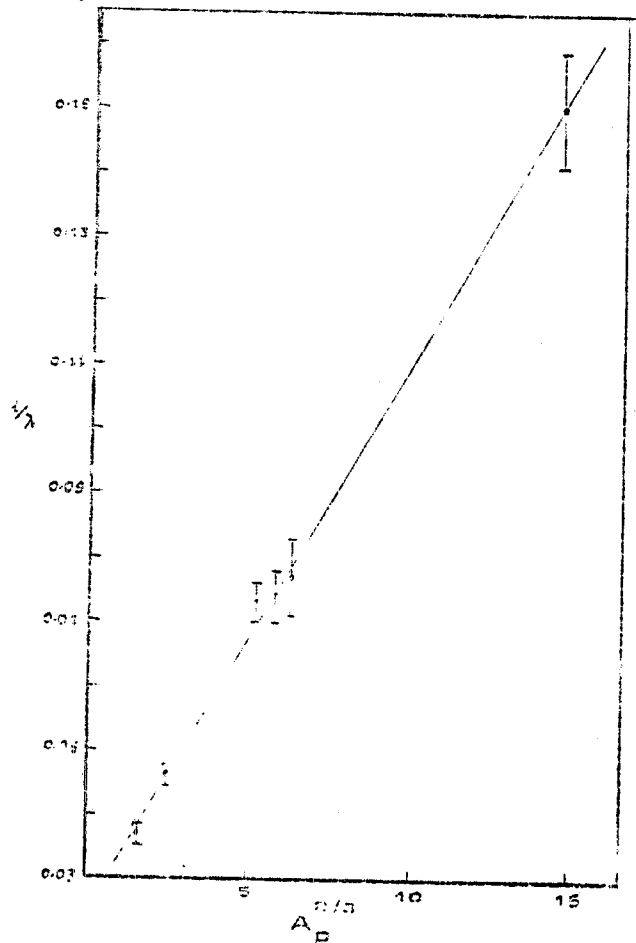


FIG. 1 - The inverse of the inelastic mean free path $1/\lambda$ plotted against $A_p^{2/3}$, where A_p is the projectile mass number. The experimental points are taken from our experiment and from refs. (25-28).

where A_p is the projectile mass number. The agreement of data, demonstrated in Fig. 1, and the previous analysis^(22,25), show that the calculations carried out according to simple geometric models^(11,24) are in a satisfactory agreement with the experimental cross sections.

For the present analysis 852 inelastic interactions of ^{12}C ions with emulsion at 4.2 GeV/nucleon were used. The charged secondary particles, in these events, were classified into the following:

- 1) Relativistic particles or showers (s) of relative ionization $g/g_0 < 1.4$, where g is the particle track ionization and g_0 is the ionization at the "plateau". Tracks of such type but with an emission angle $\theta \leq 3^\circ$ were further subjected to rigorous multiple scattering measurement for momentum determination and consequently for separating produced pions from single charged projectile fragments (protons, deuterons and

tritons)^(22,23,27,28). About 10% of the measured tracks were identified as pions, 70% protons 15% deuterons and 5% tritons.

- 2) Grey particle tracks (g) with $L > 3$ mm and $g/g_0 > 1.4$ and having dip angle $\alpha < 30^\circ$.
- 3) Black particle tracks (b) with $L \leq 3$ mm and $\alpha < 30^\circ$. In order to take into account g and b tracks with $\alpha > 30^\circ$ a geometrical weighting factor W was attached to every b and g particle track, such that

$$W = 1 \quad \text{when } 150^\circ \leq \theta \leq 30^\circ$$

$$\text{otherwise} \quad W = \pi/2 / \text{arc sin}(\sin 30^\circ) / \sin \theta$$

To distinguish between g and b particles and projectile multiply charged fragments, we define two further types of particles.

- 4) Double-charged $Z=2$ projectile fragments with $g/g_0 \approx 4$, $\theta < 3^\circ$ and without any change in ionization along a length of at least 2 cm from the interaction vertex. For more confirmation of this criterion the ionization of these tracks were compared to the distinguishable tracks of events $^{12}\text{C} + \text{A} \rightarrow \text{A} + 3\alpha$ where A is an emulsion nucleus.
- 5) Multicharged $Z \geq 3$ projectile fragments having relative ionization $g/g_0 = 6$, $\theta < 3^\circ$ and without any change in ionization along a length of at least 1 cm from the vertex. Further, the δ -electron density was measured for these tracks and they were subdivided into $Z=3, 4, 5$ and 6 fragments.

Thus we adequately divided the emitted particles into projectile and target fragments. Moreover, projectile fragments are subdivided into $Z=1, 2, \dots, 6$ charged projectile fragments. This will enable us to compare our results with^(13,14,18,26-31). In each star, the total charge of the projectile fragments $Z^* = \sum N_i Z_i$ was estimated, where N_i is the number of projectile fragments having charge Z_i in the given event. Then, the number of projectile interacting nucleons ν was determined from the approximate relation $\nu = 12 - 2Z^*$. In the present paper our attention is paid mainly to the central collisions.

3. - SELECTION CRITERIA OF CENTRAL COLLISIONS

There is no strict definition of what we mean by central collisions. Instead the selection criteria used in experiments to skip peripheral reactions determine the degree of centrality⁽²⁰⁾. In the present paper we define central collisions as those events which have no observable projectile fragment, even a singly charged one, emitted within 3° of the incident beam direction. In fact we suppressed our statistics by 10% only when we avoided, for central collision events, the emission of any shower track including pion tracks, within 3° of the beam direction. Thus out of 852 inelastic interactions of ^{12}C ions with emulsion, 119 events were selected as central collisions. This corresponds to 14% of all events. These are complete central collisions except a very small probability that some projectile neutrons may pass through the target without interaction while all protons interact. However, these are the most central collisions which had ever been studied yet.

In refs. (12,32,33), events with $n_h (=n_b + n_g) \geq 28$ were chosen to represent central collisions of ^1H , ^2H , ^4He and ^{12}C with Ag, Br emulsion nuclei. According to our selection criterion, only 60% of their ^{12}C events will represent central collisions with Ag, Br emulsion nuclei. In refs. (25,29), the authors studied the interaction of ^4He , ^{12}C , ^{14}N and ^{16}O ions with emulsion at 2.1 GeV/nucleon. They defined central collisions as the events which have no beam-velocity $Z \geq 2$ projectile fragment emitted within 5° of the beam direction. The percentages of central collisions in these interactions are 34.9, 29.7, 35.5 and 24.3 respectively. Their value of ^{12}C central event (29.7%) is two times larger than ours (14%). However if we apply their criterion of central collisions to our data, we shall have 43.9% central events which is 1.5 times their value. This disagreement may be due to different

measuring techniques and defining criteria of particle types. Although, it is to be noted that the data of refs. (25,29) are not consistent with each other. One can not understand that ^{14}N has central collisions more frequent than ^{12}C under the same conditions. The opposite is expected. If the ^{12}C datum is deleted, the rest of data will obey the expected trend i.e. the centrality decreases with the projectile mass. Thus we have shown that our sample is the most central case which had ever been studied yet.

4. - MULTIPLICITIES OF SECONDARY PARTICLES

The n_h -distribution, for central collisions of ^{12}C ions with emulsion at 4.2 GeV/c per nucleon, is presented in Fig. 2. There is an increasing in the frequency of events at $n_h=7$, but there is no statistically significant peak at

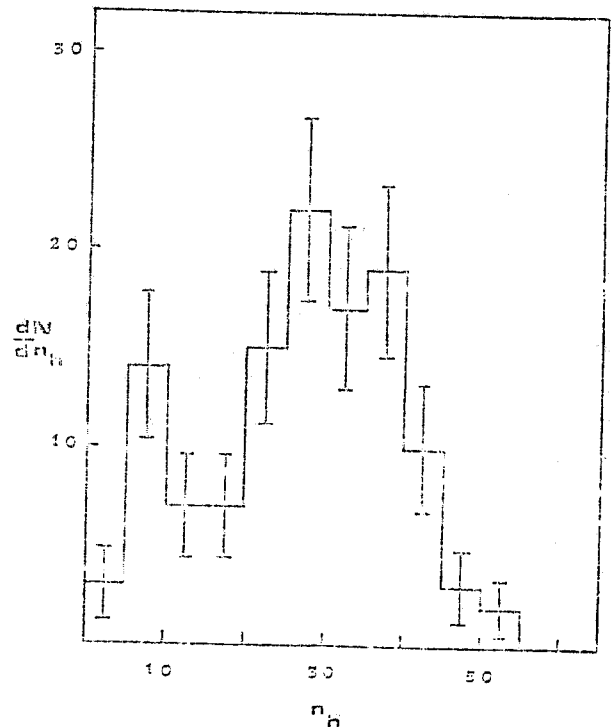


FIG. 2 - The n_h -multiplicity distribution of particles emitted from central collisions and having normalized ionization $g/g_0 \geq 1.4$, corresponding to proton energy ≤ 400 MeV.

this value which would have been interpreted as central collisions with the group of light emulsion nuclei CNO. If we even put $n_h=8$ as an upper limit for the CNO group, only 7 events out of 119 are attributed for light nuclei. Thus we can conclude that central collisions of our experiment occur mainly with Ag, Br nuclei and the number of such collisions with CNO group is negligably small. The ratio between the number of central events occurring with CNO and Ag Br group is given by $(N_{\text{CNO}}/N_{\text{Ag, Br}}) = N(n_h < 7)/N(n_h \geq 7) = 4/119$. In spite of the difference in the selection criteria of central collisions and in the energy limits of the emitted particles, this result agree with ref. (18). This is expected, since the difference between the two experiments is basically in the degree of centrality which does not distort the general behaviour of the n_h -distribution. On the contrary, papers (13,14) which are devoted to the investigation of central collisions of $Z \geq 3$ cosmic ray nuclei with emulsion at energy higher than 100 GeV/nucleon. The author of these papers found no events between $n_h=5$ and $n_h=10$, he calculated, from the experimental data, the ratio $N_{\text{CNO}}/N_{\text{Ag, Br}} = 15/21$. This result disagrees with ours and that of ref. (18). The disagreement may be due to that in (13,14) the projectile nuclei were mainly light nuclei i.e. lighter than ^{12}C ions.

Table I presents the average multiplicity values for secondary particles of different types emitted in central collisions of ^{12}C ions with emulsion nuclei at 4.2 GeV/c per incident nucleon. These values are compared with the

TABLE I - The average multiplicities of different particles emitted in p-emulsion and central ^{12}C -emulsion collisions.

projectile \ multiplicity	$\langle n_s \rangle$	$\langle n_g \rangle$	$\langle n_b \rangle$
^{12}C	17.3 ± 0.6	16.6 ± 0.9	8.8 ± 0.5
P	1.6 ± 0.1	2.2 ± 0.1	4.6 ± 0.2

corresponding ones for proton emulsion interactions at the same energy per nucleon⁽²²⁾. It is interesting to notice that $\langle n_s \rangle_{^{12}\text{C}} / \langle n_s \rangle_{\text{PA}} = 17.3/1.6 = 11$, whereas the projectile mass number is $A=12$. This result can be used as a basis for assuming that, in central collisions, the multiplicity of generated particles is the result of A independently interacting nucleons. The idea of considering nucleus-nucleus interaction a superposition of nucleon-nucleon collisions is valid not only for zero impact parameter collisions but also for interactions of larger impact parameter. This can be seen clearly from the comparison of $\langle n_s \rangle$ for central ^{12}C A interactions with $\langle n_s \rangle$ for all events of these interactions. The ratio between these two values is nearly equal 2, in good agreement with the calculated average number of projectile interacting nucleons $\langle \nu \rangle = 6$ for all events. This means that the average number of generated particles per projectile interacting nucleon $\langle n_s \rangle / \nu$ is approximately constant. Table 2 illustrates this experimental fact, not only for s-particles but also for g- and b-particles. It presents the average multiplicities at different values of ν i.e. at various impact parameters. These results are consistent with those of ref. (22,30) and they give evidence for the validity of considering nucleus-nucleus interaction a multiple nucleon-nucleon collision. It is worthy to mention that in a previous paper⁽¹⁶⁾, we simulated ^{12}C emulsion interactions using a modified cascading evaporation model which considers the interacting nuclei as two Fermi gas clouds of nucleons. The interaction between each pair of nucleons is followed in time by the Monte-Carlo method (for details of the model see ref. (16)). A good agreement of the model predictions with the experiment was demonstrated.

TABLE II - The average multiplicities of different particles versus the number of interacting projectile nucleons.

$\langle \nu \rangle$ \ multiplicity	$\langle n_s \rangle$	$\langle n_g \rangle$	$\langle n_b \rangle$
12	17.3 ± 0.6	16.6 ± 0.9	8.8 ± 0.5
10	13.7 ± 0.5	10.5 ± 0.8	7.6 ± 0.6
8	10.1 ± 0.5	7.1 ± 0.7	5.4 ± 0.5
6	7.7 ± 0.3	6.1 ± 0.3	4.4 ± 0.2

The authors of ref. (34) studied the multiplicity distribution of produced particles in high-energy cosmic ray interactions. They concluded that the multiplicity variance does not agree with the hypothesis that the nucleons of the colliding particles interact independently, and that the multiplicity distribution in central nucleus-nucleus interactions is similar to the corresponding one in hadron-hadron interactions. This conclusion contradicts our data and those of ref. (29).

Fig. 3 shows the n_s -multiplicity distribution of our central collisions, curve 1 is a Poisson distribution $P(n) = \langle n \rangle^n e^{-\langle n \rangle} / n!$ where $\langle n \rangle = 17.3$ and $n=0, 1, 2, \dots$ etc. Within statistical errors the experimental histogram

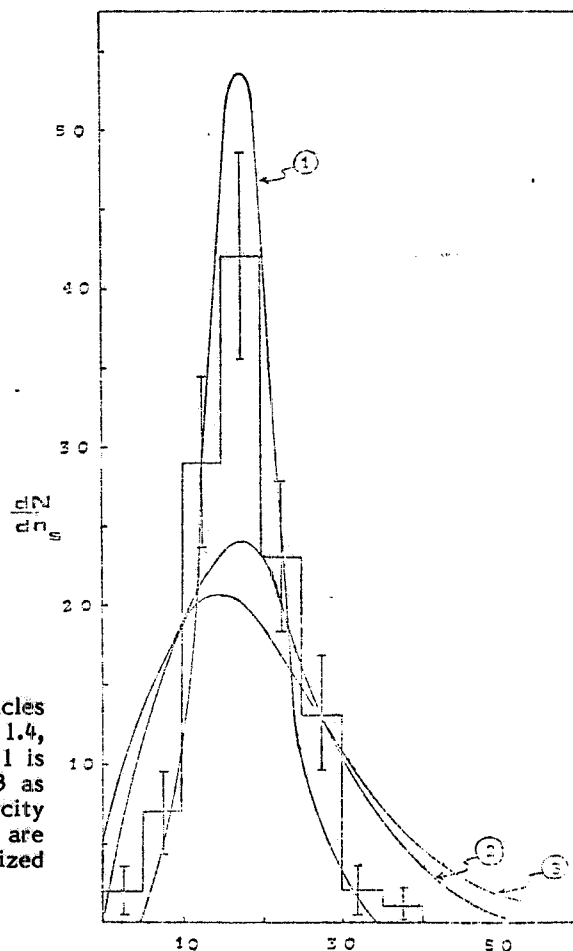


FIG. 3 - The n_s -multiplicity distribution of particles emitted from central collisions and having $g/g_0 < 1.4$, corresponding to proton energy > 400 MeV. Curve 1 is the Poisson distribution with $\langle n \rangle$ equals to 17.3 as given in Table I. Curves 2, 3 are universal multiplicity distribution of pp and p-nucleus respectively which are rescaled to our $\langle n_s \rangle$. All distributions are normalized to the same number of events.

agrees with the Poisson distribution. This is an important result since Gyulassy and Kauffmann⁽¹⁰⁾ had shown that for thermodynamic fireball and a wide range of dynamical models, the Poisson multiplicity distribution is expected for a fixed-impact-parameter nucleus-nucleus collisions, if there are no strong correlations between the produced pions. A similar results were obtained by different techniques^(17,35,36). Another confirmation for our conclusion comes from the comparison of curves 2 and 3 with our experimental n_s -distribution. Curves 2 and 3 are universal multiplicity distributions for p-nucleus and p-p interactions, obtained according to the KNO scaling⁽¹⁹⁾ and rescaled to our $\langle n_s \rangle$ for central collisions of ^{12}C ions with emulsion. It is clear that our experimental n_s -distribution of the central collision is narrower than the corresponding distribution of pp interactions. This result contradicts that of ref. (34) and agrees with the data of^(13,14,35,36). all these analyses lead to the conclusion that nucleus-nucleus interactions can be viewed as multiple nucleon-nucleon collisions.

Table I shows also the average multiplicities of grey $\langle n_g \rangle$ and black $\langle n_b \rangle$ particle tracks. It is interesting to notice that the average number of grey particles (participants) is twice the number of black particles (spectators) whereas at $\nu < 6$ this ratio is less than unity⁽²⁰⁾. This can be explained by the increasing of the participants volume. The number of participating protons which nearly equals the number of grey particles can be calculated roughly from a pure geometrical considerations. The number of participating protons from the projectile, in case of central collisions, is simply equal to its charge number Z_p . To calculate the number of participating protons from the target, we assume that one has to take all protons from the target which lie in the cylinder cut by the projectile. Approximate length of this cylinder equal the target nucleus diameter $2R_T$, the cross sectional area of which is πR_p^2 , therefore its volume equals $2R_T \times \pi R_p^2$. Dividing this volume by the target nucleus volume $\frac{4\pi}{3} R_T^3$ and multiplying by Z_T , we obtain the number of participant protons from the

target. Thus the total number of participant protons equals $Z_P + Z_T (3 A_P^{2/3} / 2 A_T^{2/3})$. Thus for ^{12}C central collisions with emulsion, the number of participant protons equals 19.6. This number does not disagree with the $\langle n_g \rangle$ given in Table I, especially if we realize that some of these participating protons may acquire energy higher than the limit of grey particles. This analysis shows that the clean cut fireball model can explain the great number of grey particles observed in central nucleus-nucleus interactions. This conclusion agrees with the data of (20).

5. - ANGULAR DISTRIBUTION OF SHOWER TRACKS

Fig. 4 presents the pseudo-rapidity ($\eta = -\ln \tan \theta/2$) of shower tracks from the central collisions of ^{12}C ions

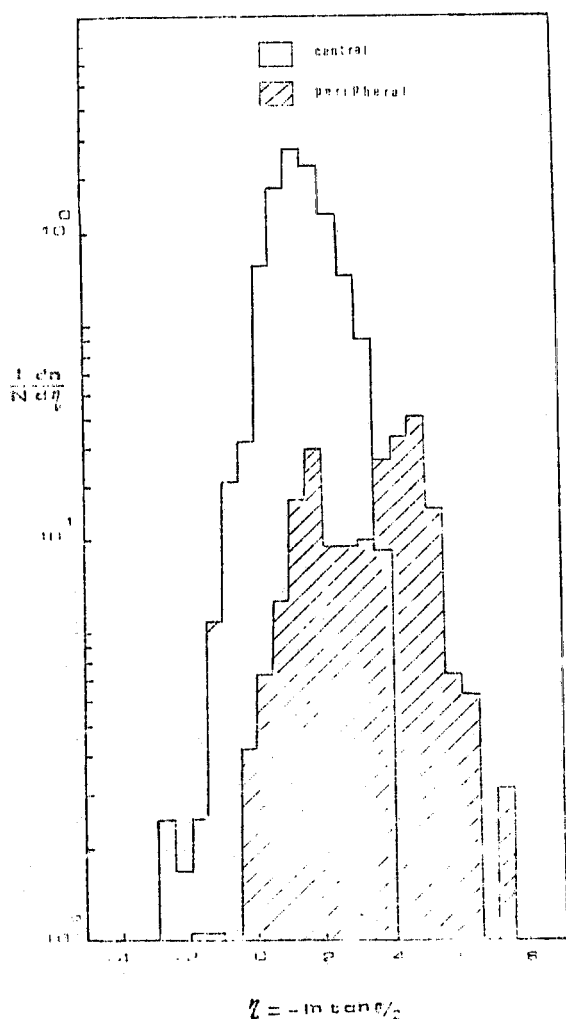


FIG. 4 - The rapidity ($\eta = -\ln \tan \theta/2$) distributions of showers emitted in central and peripheral collisions.

with emulsion, in comparison with the corresponding distribution for the most peripheral events i.e. those with $Z^* = 6$. From the figure, we can see that the distribution of central collisions is a smooth one, extending from the target fragmentation region to the center of projectile fragmentation region. This is expected because in central collisions all projectile nucleons interact and they are no longer spectators but participants which may acquire any value of rapidity between the two fragmentation regions. In contrast with this distribution is that of the most peripheral events. In the later distribution we notice two clear regions, the projectile and target fragmentation regions. These two limiting regions are quite distinguished as seen in Fig. 4. This result gives an evidence for the

limiting fragmentation hypothesis which implies that both projectile and target may be fragmented irrespective of each other.

6. - ANGULAR DISTRIBUTIONS OF TARGET FRAGMENTS

Fig. 5 presents the angular distribution of g-particles emitted in central collisions of ^{12}C ions with emulsion at 4.2 GeV/nucleon. This distribution is compared with the corresponding one from PA interactions at 6-400 GeV. Also the distribution of g-particles from all ^{12}C interactions (i.e. with $\langle \nu \rangle = 6$) is presented in the same figure. It is seen, as it has been noted in many papers (12,20,22), that the angular distribution of grey particle tracks is very weakly dependent on the variation of projectile mass, primary energy and the target mass. This phenomenon was christened "conservatism" by Tolostov^(12,21,32,33). Heckman et al.⁽¹⁸⁾ studied the angular distribution of $E \leq 250$ MeV/A, $E < 31$ MeV/A target fragments, emitted in central collisions of ^4He , ^{16}O and ^{40}Ar at beam rigidity $PC/Zc=5.7$ GV. They noted that the average number of $E < 31$ MeV/A fragments decreases and that of $31 < E \leq 250$ MeV increases with the increasing of projectile mass number. This result can be interpreted if we recall in mind the fire-ball picture. The numbers of participant nucleons increases as the volume of the cylinder cut by the projectile in the target nucleus increases. As the mass of the projectile increases the cross sectional area of this cylinder increases and consequently the number of participants. The size of target nucleus is limited and consequently the number of evaporated particles decreases when n_g increases.

Fig. 6 shows the angular distributions of black particle tracks, i.e. tracks with range $L \leq 3000 \mu\text{m}$ which is equivalent to proton kinetic energy ≤ 27 MeV, emitted from central collisions, all interactions of ^{12}C ions with emulsion and from proton emulsion interactions at 2.3 GeV. Within statistical errors the distributions are consistent with each other. The forward to backward ratio F/B i.e. the number of such tracks emitted at angles $> 90^\circ$ to those emitted at angles $< 90^\circ$, was calculated for central and all collisions. The values of F/B equals

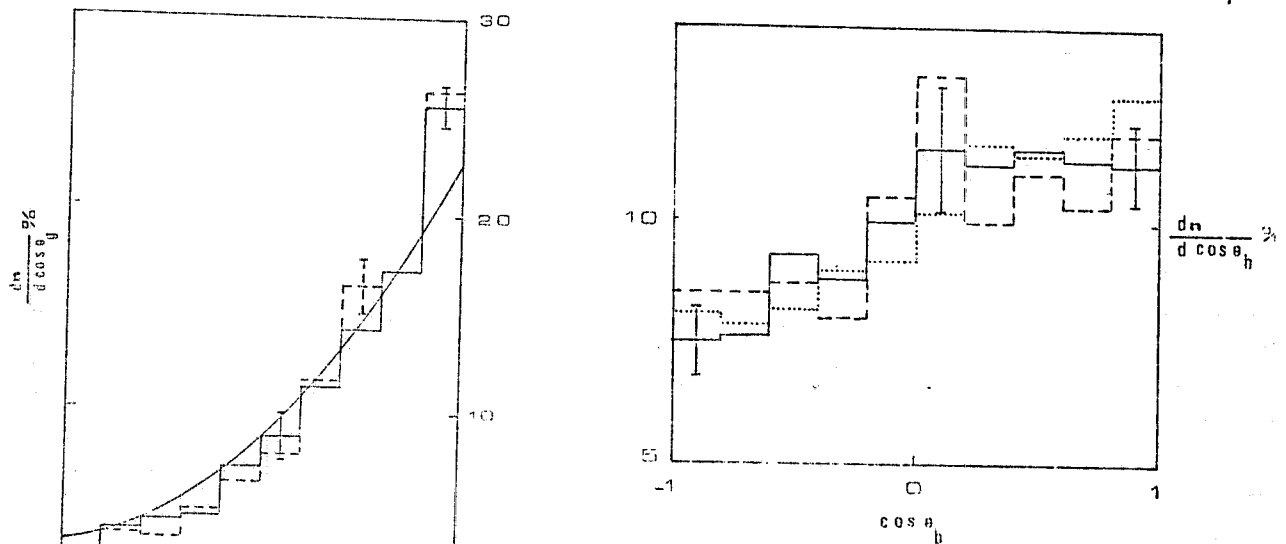


FIG. 5 - The angular distributions of g-particles: the continuous histogram for all events, the dashed one for central collisions and the curve for p-emulsion at energy 6-400 GeV (see ref.(20)).

FIG. 6 - The angular distributions of b-particles which correspond to proton energy ≤ 27 MeV. The dotted histogram for p-emulsion at 2.3 GeV (see ref. (30)), the dashed one for central collisions and the continuous lines for all events of ^{12}C -emulsion.

$1.25^{+0.09}$ and $1.31^{+0.05}$ respectively. We notice that although the statistical uncertainties in these values are large, they are consistent with each other, indicating an approximate isotropy of the low-energy particles. This behaviour is nearly independent on the projectile mass or the impact parameter. For further investigation of this phenomenon the ratio F/B was calculated for $\nu = 10, 8$ and ≤ 6 . These values are $1.38^{+0.10}$, $1.23^{+0.12}$ and $1.34^{+0.08}$ respectively. We also calculated this ratio for light target nuclei $n_h < 7$ and for Ag, Br emulsion nuclei, the values of F/B are $1.42^{+0.13}$ and $1.29^{+0.05}$. For interactions of ^{14}N ions with emulsion at 2.1 GeV/nucleon⁽³⁰⁾, the value of $F/B=1.40^{+0.06}$. All these results give more confirmation to our previous conclusion about the independence of the angular distribution of the soft component on the projectile mass, the impact parameter or the target nucleus. This conclusion agree with data of⁽¹⁸⁾.

The angular distribution of $E < 31$ MeV/A target fragments was fitted with a double-parameter Maxwellian distribution in ref. (18). From the results of fitting, it was found that the longitudinal velocity of the center of mass of the emitting system $\beta_{11}=0.015^{+0.002}$ and the characteristic spectral velocity of this system $\beta_0=0.115^{+0.002}$. Our black particle tracks have energy ≤ 27 MeV/A, so it is interesting to compare our angular distribution of b-tracks with the theoretical distribution obtained in ref. (18) with the above parameters. Fig. 7 shows that our experimental angular distribution of soft fragments can be described with a double-parameter Maxwellian distribution, the values of these parameter are given above. We notice that value of β_{11} , deduced from the fitting, coincides with the value given by $\beta_{11} = \beta_0 \cos \theta_m$, where θ_m is the median angle i.e. the angle at which

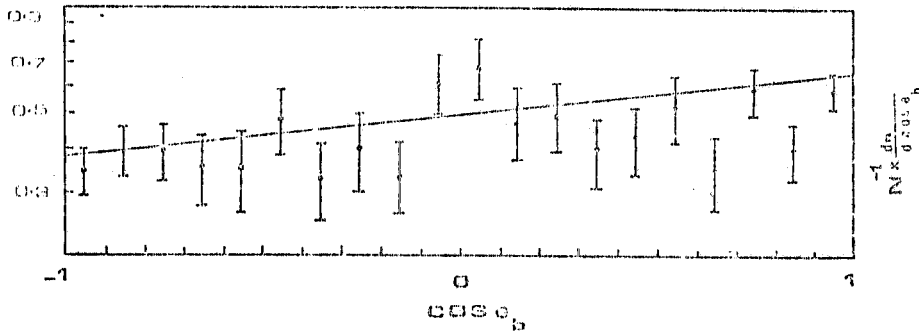


FIG. 7 - The angular distribution of b-particles, emitted from central collisions, in comparison with theoretical Maxwellian distribution taken from ref. (18).

half the particles are emitted. In our experiment $\theta_m = 83^\circ$ for the black tracks, putting $\beta_0 = 0.115$ in the previous relation we obtain $\beta_{11} = 0.014$ in a good agreement with the value deduced from the fitting. This result shows that the emitting system is slow and of typical longitudinal velocity $\beta_{11} = 0.014^{+0.002}$. These results indicate that the angular distribution of b-tracks is nearly isotropic, irrespective of the impact parameter. The temperature of the emitting system $\tau = M \beta_0^2 / 2$, where M is the nucleon mass, is 6 MeV per nucleon which equals approximately the binding energy of a nucleon.

We calculated the F/B ratio for all h tracks i.e. for particles equivalent to proton energy $E < 400$ MeV. This ratio for our central collisions equals $2.39^{+0.05}$. In ref. (18) the authors determined the F/B ratio of target fragments equivalent to proton energy ≤ 250 MeV, emitted from central collisions of ^4He , ^{16}O and ^{40}Ar with emulsion. The values of F/B are $1.94^{+0.05}$, $1.82^{+0.06}$ and $2.54^{+0.07}$ respectively. Taking into consideration that our energy limit of particles (400 MeV/A) is higher, our events are more central and our primary energy per nucleon is larger than⁽¹⁸⁾, we conclude that our value of F/B is not in disagreement with these results.

The angular distributions of black and grey particles display no significant peak which could be attributed to shock waves.

7. - CONCLUSIONS

The study of 4.2 GeV/nucleon ^{12}C -emulsion inelastic interactions, leads to the conclusion that the experimental value of the mean free path of nucleus-nucleus inelastic interactions, are in a satisfactory agreement with the geometrical models such as for example the "soft spheres" model.

From the investigation of particles emitted in the central ^{12}C -emulsion collisions, we can make the following conclusions:

- 1- The sample studied in this paper, represents the most central collisions which had ever been studied yet. These collisions occur mainly with Ag, Br emulsion nuclei and only a negligible number of events may be attributed to light emulsion nuclei.
- 2- Central nucleus-nucleus interactions can be considered as superposition of nucleon-nucleon collisions. This conclusion is drawn from, the comparison of $\langle n_s \rangle$ for central ^{12}C -emulsion with $\langle n_s \rangle$ for p-emulsion interactions and the constancy of $\langle n_s \rangle$ per interacting projectile nucleon.
- 3- The n_s -distribution is nearly a Poisson one which indicates the absence of correlation between the produced pions. This distribution is narrower than the corresponding ones for p-p and p-nucleus.
- 4- The clean cut fireball model can explain the large number of the emitted grey particles.

The study of angular distributions of different particles, enables us to make the following conclusions:

- 5- The angular distribution of shower tracks agrees with the hypothesis of the limiting fragmentation.
- 6- The angular distributions of target fragments are independent on the projectile mass, the impact parameter and on the target nucleus.
- 7- The target fragments angular distributions show no statistically significant peak which could be attributed to "shock waves".
- 8- The angular distribution of b-tracks is consistent with a Maxwellian distribution. The longitudinal velocity of the emitted system is slow and typically equals $(0.014 \pm 0.002)c$. The temperature is about 6 MeV which is near to the binding energy of the nucleon.

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