Central $^{12}$C-Emulsion Collisions at 4.5 $A$ GeV/c (*).

M. S. Ahmad, M. Q. R. Khan, K. A. Siddiqui and R. Hasan

Department of Physics, Aligarh Muslim University - Aligarh, 202002, India

Summary. — Central collisions of $^{12}$C with emulsion nuclei at 4.5 $A$ GeV/c have been investigated. Central collisions are defined as events with $N_h > 28$ and having no observable projectile fragments emitted within 3° of the beam direction. The probability of central collisions is found to be 11.68% and it increases with the mass of the projectile. The multiplicity distribution of shower particles is a Poisson one which indicates the absence of correlations between the produced pions. F/B for black and grey particles are 1.40 ± 0.04 and 2.95 ± 0.10, respectively, and no peaks are observed in the angular distribution of target fragments which could be attributed to the shock-wave phenomenon. Evidence of strong correlations between the produced particles has been obtained. This indicates that the particle production in nucleus-nucleus collisions takes place via cluster production. However, the absence of higher-order correlations rules out the possibility of the production of quark-gluon plasma, in these collisions. Furthermore, no evidence is found the production of fireball-type heavy clusters predicted by Adamovich et al.

PACS 25.70.Np – Fragmentation and relativistic collisions.

1. – Introduction.

Recently it has been speculated theoretically that when the energy density and temperature of nuclear matter is very high, it may undergo a phase transition and a number of exotic phenomena, e.g., density isomers, shock waves, production of quark-gluon plasma, etc. might occur[1-4]. Conditions of high density and temperature could be achieved in central nucleus-nucleus collisions. This has generated a lot of interest in the study of central collisions. The study could provide valuable information about the behaviour of nuclear matter under extreme conditions. Moreover the characteristics of central collisions can be more critical to the choice of interaction model than are the characteristics of average nucleus-nucleus collisions.

It is now well established that multiparticle production in nucleon-nucleon and nucleon-nucleus collisions can be understood in terms of the cluster model. According

(*) The authors of this paper have agreed to not receive the proofs for correction.
to the model, a hadron system (cluster) is produced when a nucleon collides with another nucleon. This cluster then achieves the asymptotic state of free secondary particles. Particles from the decay of different clusters overlap each other on the rapidity scale. This gives rise to short-range correlations among the secondary particles. The short-range correlations in π-nucleon and π-nucleus collisions at accelerator energies and in nucleon-nucleon and nucleon-nucleus collisions at accelerator, ISR, collider and cosmic-ray energies have been extensively studied [5-12]. However, only a few attempts have been made to study correlations in nucleus-nucleus collisions [13, 14]. Recently Kapoor et al. [14] have found evidence of strong correlations between particles produced in π-nucleus collisions at cosmic-ray energies. This indicates that production of particles in nucleus-nucleus collisions also takes place via cluster formation. However, in the case of nucleus-nucleus collisions, unlike nucleon-nucleon or nucleon-nucleus collisions, there are several nucleons in the projectile. A question that naturally arises is: do the nucleons in the projectile and the target act independently of each other or do they interact collectively? A study of correlations in nucleus-nucleus collisions would provide an answer to this question.

In the present paper, we study the central $^{12}$C-emulsion collisions at $4.5\,\text{A GeV/c}$. Multiplicity distributions of shower, grey, black and heavy particles have been studied. Angular distributions of shower, grey and black particles have also been studied with a view to find if there are any peaks in the distributions which would be attributed to the shock-wave phenomenon. Present data are compared to the data of p-nucleus and nucleus-nucleus collisions. Finally, the correlations among the secondary particles produced in central $^{12}$C-emulsion collisions have also been studied.

2. - Experimental details.

A stack of 600 $\mu$m thick emulsions exposed to a $4.5\,\text{GeV/c}$ per nucleon $^{12}$C beam at Dubna synchrophasotron was used. 3065 inelastic collisions of $^{12}$C were picked up by following 42.269 cm of primary beam, leading to the collision mean free path of $^{12}$C in emulsion $\lambda = (13.79 \pm 0.25)\,\text{cm}$. 2550 collisions were finally selected, without any bias, for the final analysis. Details of classification of events, selection criteria and measurements are already given in our earlier papers [15, 16].

Tracks of secondary particles were classified into different categories according to the standard emulsion criteria. Central collisions were defined as events with $N_h \geq 28$ and having no observable projectile fragments, even singly charged one, emitted within $3^\circ$ of the beam direction. Out of 2550, only 298 events satisfied the criteria for centrality. Our criteria ensure that these events are due to the central collisions of $^{12}$C with AgBr nuclei.

3. - Experimental results.

3’1. Probability of central collisions. - There are no standard criteria for selecting central collisions. Different workers have used different criteria for defining central collisions. Heckman et al. [17] have studied the central collisions of $^4\text{He}$, $^{12}\text{C}$, $^{14}\text{N}$ and $^{16}\text{O}$ nuclei with emulsion at $2.1\,\text{A GeV/c}$. They defined central collisions as the events