Interesting Features of Catastrophic Destruction of ^{12}C-AgBr Collisions at 4.5 AGeV

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Abstract: ***An attempt has been made to study some interesting results on catastrophic destruction of ^{12}C-AgBr collisions at 4.5 AGeV. Results shows that mean normalized pseudorapidity density increases rapidly in the target fragmentation zone. The variation of average number of intra-nuclear collisions<ν> with various parameters, multiplicity correlation and multiplicity distribution has been studied. Furthermore, the dependency of mean normalized multiplicity and reduced multiplicity on total energy available in the centre of mass system has also been investigated.***

Keywords: Catastrophic destruction, normalized pseudorapidity, target fragmentation, intra-nuclear collisions, multiplicity correlation, multiplicity distribution, mean normalized and reduced multiplicities.

1. Introduction

Study of secondary charged particles produced in central relativistic heavy ion interactions is attracting a great deal of attention during the recent years [1-7].It may be due to the fact that the study of totally disintegrated events produced in heavy ion collisionsin which almost the whole projectile takes part in there actions [20-22]. During the catastrophic destruction, nuclei may be compressed to more than their normal density and nuclear matter may undergo to phase transition of hadron gas into quark gluon plasma. The study of such a state would help answer some of the cosmological questions because formation of QGP is visualized to take place in collapsing stars. Hence the creation of fluctuation in the early universe could be explained by studying the formation and properties of QGP. Furthermore, it is reported that the density at the centre of the neutron star is expected to be 3 to 4 times the normal density. Therefore, if they exist at these densities, pion condensation and quark matter may play a key role in investigating the properties of these highly compressed stellar objects. The relativistic heavy ion collisions probably provide the only means of simulating these conditions in the laboratory. Such study may help in refining various models put forward for explaining the mechanism of multi-particle production in high energy nucleus-nucleus interactions.

2. Experimental Technique

In the present work an emulsion stack of several pellicles of NIFKI-BR2 type is used. The size of each Pellicle is 18.7×9.7×0.06cm3.The stack was exposed by 4.5AGev carbon nuclei at Dubanasynchrophasotran, Russia. A random sample of 681events was picked up by using along the track doubly scanning method. All charge secondary produced in an interaction are classified in accordance with their ionization or normalized grain density (g*), range (L) and velocity (β) into the following categories:

2.1 Shower tracks (N_s): These are freshly created charged particles with g* less than 1.4. Theseparticles have relativistic velocity β > 0.7. They are mostly fast pions with a small mixture of Kaons and released protons from the projectile which have undergone an interaction. For the case of proton, kinetic energy (E_p) should be less than 400 MeV.

2.2 Grey tracks (N_g): Particles with range L > 3 mm and 1.4 < g* < 6.0 are defined as greys. They have β in the range of 0.3 < β < 0.7. These are generally knocked out protons of targets with kinetic energy in between 30 - 400 MeV, and traces of deuterons, tritons and slow mesons.

2.3 Black tracks (N_b): Particles having L < 3 mm from interaction vertex from and g* > 6.0.This corresponds to β < 0.3 and protons of kinetic energy less than 30 MeV. Most of these are produced due to evaporation of residual target nucleus.

The number of heavily (N_h) ionizing charged particles (N_h) are part of the target nucleus isequal to the sum of black and gray fragments ($N_h = N_b + N_g$).

All the experimental details may be found in our earlier publication [2].

3. Experimental Results and Discussions

3.1Dependence of mean multiplicity onthe average number of intra-nuclear collisions, <ν>

In fig.1, variations of $<N_b>$, $<N_g>$, and $<N_s>$ for total disintegration events with the average number of intra-nuclear collisions,<ν> are plotted. The value of <ν> is obtained by using a phenomenological formula of the following form [8]:

$$<\nu>=0.73A_p^{0.72} \quad (1)$$

Here A_p represents the mass of the projectile. The experimental data are found to satisfy the following relationship obtained by the method of least squares:

$$<N_b>= (-1.07 \pm 0.23)<\nu>+ (17.14\pm0.83) \quad (2)$$

$$<N_g>= (0.98\pm0.23)<\nu>+ (15.98\pm0.99) \quad (3)$$

$$<N_s>= (4.50\pm0.58)<\nu>+ (-2.64\pm0.65) \quad (4)$$

It may be noticed in the figure that the total disintegration events are characterized by a rapid growth of $<N_s>$ as compared to the corresponding values for the total ensembles of elastic interactions. This result may be explained in terms of the predictions of the superposition model [8]. A similar result has been obtained by Tauseef et al [9].

3.2 Normalized pseudorapidity density

To investigate the characteristics of charged shower particles, we examine the behavior of the normalized pseudorapidity density r(η), defined as:

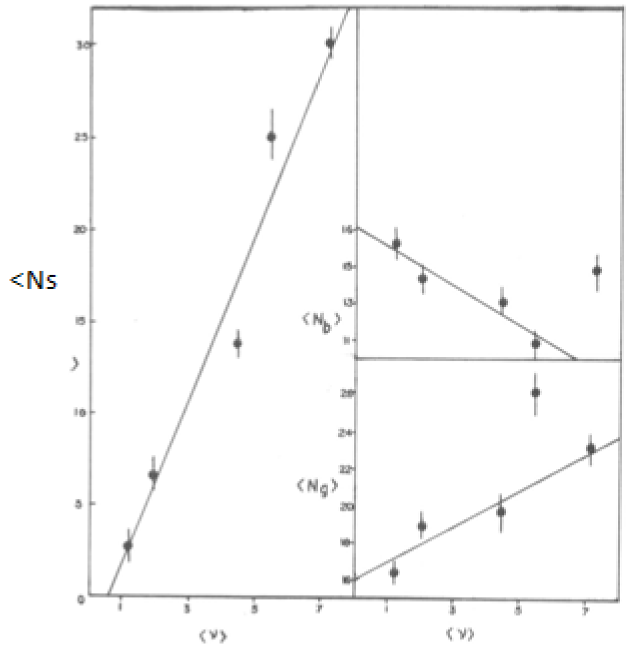

Figure 1: Dependence of $<N_b>$, $<N_g>$, and $<N_s>$ on $<\nu>$

$$r(\eta)= \frac{1}{\sigma_{BA}}\frac{dN_{BA}}{d\eta} \Big/ \frac{1}{\sigma_{BN}}\frac{dN_{BN}}{d\eta} \quad (5)$$

Where $\frac{1}{\sigma_{BA}}\frac{dN_{BA}}{d\eta}$ denotes the shower particle density determined for totally disintegrated events. The term $\frac{1}{\sigma_{BN}}\frac{dN_{BN}}{d\eta}$ represents the pseudorapidity density for the N_h $_=$0,1events having $N_h \leq 1$ in the case of nucleus-nucleus collisions at the same energy. The normalized pseudorapidity density is exhibited in the fig.3.2.It may be noticed in this fig. that r (η) is less than unity in the projectile fragmentation region for totally disintegrated events in 4.5 AGeV ^{12}C-nucleus collisions. This result suggests that the additional particles created in consecutive intra-nuclear collisions carry away some of the energy of the projectile nucleus thereby reducing its momentum in case of catastrophic destruction of heavy emulsion nuclei. It may also be seen in the fig.2 that the mean normalized pseudorapidity density increases rapidly in the target fragmentation region. This behavior may be explained in terms of the fragmentation zone hypothesis, which envisages that some more time is needed for the creation of particles in its own rest frame of reference.

3.3Variations of$<N_b>$, $< N_g>$ and $<N_h>$ on N_s:

We have plotted in fig. 3 the values of $<N_b>$, $< N_g>$ and $<N_h>$ as a function of N_s. It is observed that with increasing N_s, the value of$< N_g>$ decreases, whereas the parameters$<N_b>$ and $<N_h>$ increases linearly withN_s. Our results do not agree with [10].The experimental data shown in same fig. are found to satisfy the following relations obtained by the method of least squares:

$$<N_g>= (-0.32\pm0.12)N_s + (24.58\pm1.77) \quad (6)$$

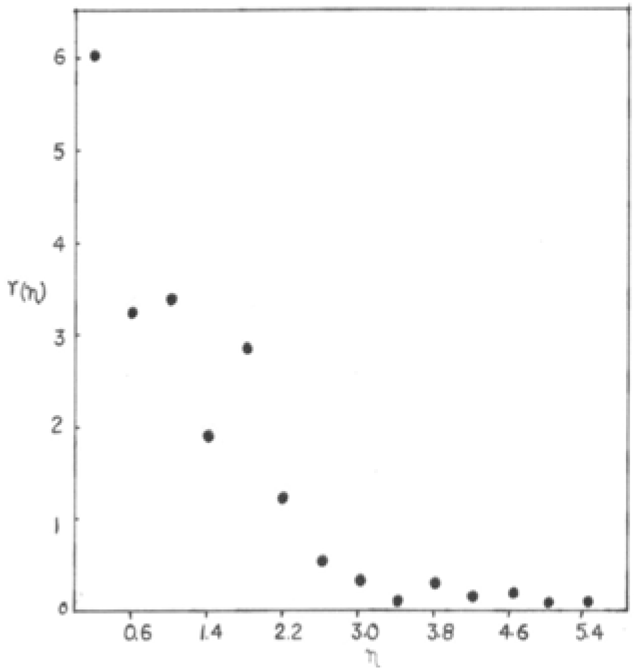

Figure 2: Normalized pseudorapidity density distribution in central collision at 4.5 A GeV

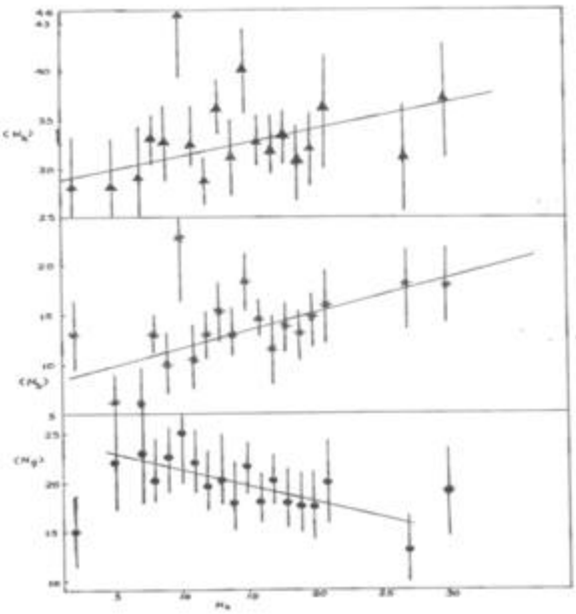

Figure 3: Variations of$<N_b>$, $< N_g>$ and $<N_h>$ on N_s

$$<N_h>= (0.28\pm0.10)N_s + (28.47\pm1.58) \quad (7)$$
$$<N_b>= (0.35 \pm0.08)N_s + (8.16\pm1.36) \quad (8)$$

3.4 Dependence of R_A and R_S on S:

For investigating the dependence of parametersR_A and R_S on the total energy available in the centre of mass system “S”. Values of S have been computed by using the geometrical model as follows [11-13]:

$$S= (M_p^2+M_t^2+2M_pE_p)^{1/2}-(M_p+M_t) \quad (9)$$

Where M_p and E_p denotes the rest mass and energy of the projectile in the laboratory system respectively, whilst M_t represents the mass of cylinder cut in the target by projectile at impact parameter b=0.

The value of M_t may be calculated by using the following expression:

$$M_t = \left(\frac{3}{2}\right)\left(A_p^{\frac{2}{3}}.A_t^{\frac{2}{3}}m\right) \quad (10)$$

Where A_p and A_t denote respectively the mass number of the projectile and target, while m is the nucleon mass.
Values of R_A and R_S have been estimated by [2, 14, 15] using equations:

$$R_A = \langle N_S\rangle_{BA}/\langle N_{ch}\rangle_{pp} \quad (11)$$
$$R_S = \langle N_S\rangle_{BA}/\langle N_S\rangle_{pA} \quad (12)$$

Where R_A and R_S are the mean normalized multiplicity and reduced multiplicity respectively. $\langle N_S\rangle_{BA}$ is the average number of charged shower particles, $\langle N_{ch}\rangle_{pp}$ refers to the average number of charged particles emitted in p-p collisions and $\langle N_S\rangle_{pA}$ denotes proton nucleus interactions at the same projectile energy.

The calculated values of R_A, R_S and S are given in Table 1 and the variations of R_A and R_S with S are shown in fig.4.

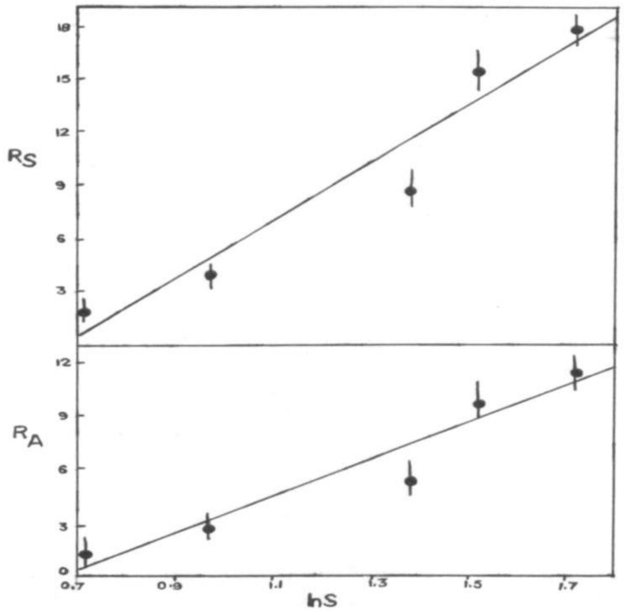

Figure 4: Dependence of R_A and R_S on S

Table1: Values of R_A, R_s, <ν> and S for different projectiles at 4.5 A G eV nucleus-nucleus collisions.

Projectile	S GeV	<ν>	R_A	R_S
Deuteron	5.10	1.20	1.14±0.29	1.78±0.12
α-particle	9.42	1.89	2.59±0.08	4.05±0.13
Carbon	24.09	4.37	5.43±0.20	8.45±0.32
Oxygen	32.98	5.37	9.88±0.45	15.39±0.70
Magnesium	47.10	7.20	11.38±0.38	17.73±0.59

This fig. displays the fact that both R_A and R_S grows linearly with increasing value of S. Values of R_A and R_S have been found to satisfy the following relationships for catastrophic events fitted by the method of least squares[19-20]:

$$R_A = (10.70\pm1.86)\ln S + (-7.29\pm2.42) \quad (13)$$
$$R_S = (16.63\pm2.89)\ln S + (-11.33\pm3.76) \quad (14)$$

3.5 Dependence of R_A and R_S on <ν>:

For investigating the dependence of R_A and R_S on the mean number of intra nuclear collisions, <ν>, we have calculated the values of <ν> by using eq. (1). The estimated values of <ν> have also been tabulated in Table1. Variations of R_A and R_S with <ν> are displayed in fig5. From this figure, it may be noticed that R_A-<ν> and R_S-<ν> relationship are linear. The following relations obtained by the method of least squares are found in a good accord with the experimental data:

$$R_A = (1.85\pm0.25)\langle\nu\rangle + (-1.05\pm1.13) \quad (15)$$
$$R_S = (2.76\pm0.35)\langle\nu\rangle + (-1.62\pm1.62) \quad (16)$$

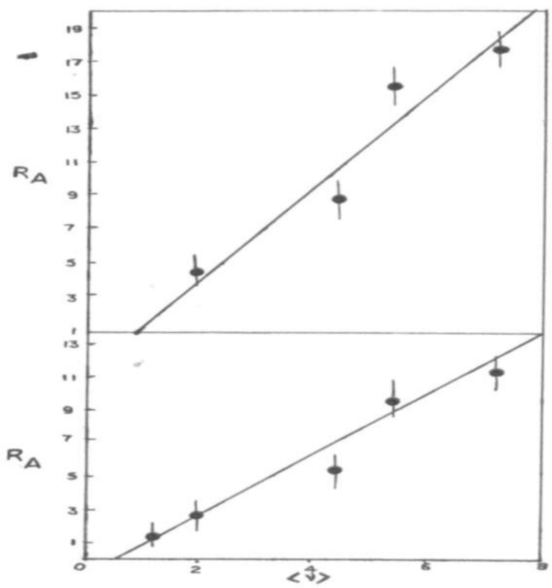

Figure 5: Dependence of R_A and R_S on <ν>

3.6 Multiplicity distributions of Shower particles in the forward and backward hemisphere:

In order to examine the behavior of the charged shower particles in the forward (θ≤90) and backward (θ≥90) hemispheres [16-18] produced in the totally disintegrated in events ^{12}C–AgBr interactions at 4.5A GeV/c, we have displayed the multiplicity distributions of shower particles in fig. 6. It may be seen from the figure that the multiplicity distribution of charged shower particles in the forward hemisphere is flatter than multiplicity distribution in the backward hemisphere. Table 2 shows the average values of charged shower particles in the forward hemisphere, $\langle N_S^F\rangle$ and backward hemisphere, $\langle N_S^B\rangle$, their dispersions, the forward to backward ratio, $F/B[= N_S^F/N_S^B]$ and the asymmetry parameter, $A_s\,[= N_S^F - N_S^B/\,N_S^F + N_S^B]$ where $D(N_S^i) = [< N_S^{i^2} > - < N_S^i >^2]^{\frac{1}{2}} \forall\, i = F\ or\ B$

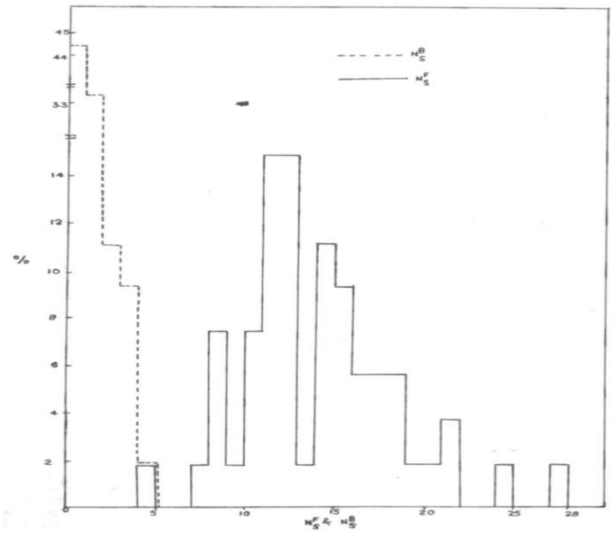

Figure 6: Multiplicity distributions of Shower particles in forward and backward hemisphere

Table2: Values of average multiplicities of Shower Particles in the forward and backward hemisphere, their dispersions ,F/B ratio and asymmetry parameter in central [12]C –nucleus interactions at 4.5GeV

$< N_S^F >$	D(N_S^F)	D(N_S^F)/$< N_S^F >$	$<N_S^B>$	D(N_S^B)	D(N_S^B)/ $<N_S^B>$	F/B	A_s
13.57±0.50	4.29±0.41	0.32±0.03	0.91±0.13	1.4±0.19	1.14±0.19	14.96±2.57	0.87

The average values of the multiplicities of shower particles, which have been listed in Table 2, indicate that the probability of the forward emission is much higher than that for backward emission. This fact is also reflected from the value of forward to backward ratio. Furthermore the asymmetry parameter A_s is also estimated for totally disintegrated events in ^{12}C-nucleus interactions at 4.5 AGeV.

4. Conclusions

On the basis of the study of the totally disintegrated events of Ag and Br nuclei caused by 4.5 AGeV carbon projectile, we draw some important conclusions which may be summarized as follows:

(i) The average multiplicity of < N_g> and <N_s> increases rapidly, with <ν>.The value of <N_b> is found to decreases with increasing value of<ν>.

(ii) The normalized pseudorapidity density r(η) is less than unity in the projectile fragmentation region for totally disintegrated events.

(iii) The parameters < N_g> and <N_s> increases rapidly with the total available energy in the centre of mass system "S" whereas the value of <N_b> decreases with the increasing value of S.

(iv) The results also reveal about the strong correlation between R_A-<ν> and R_S-<ν>.

(v) The distribution of charged shower particles produced in the forward hemisphere is flatter than the distribution in the backward hemisphere.

(vi) The probability of charged shower particles emitted in the forward direction is much higher than emitted in backward direction.

(vii) The existence of higher value of r(η) in the target fragmentation region may be explained in terms of the occurrence of some cascading effect inside the struck nucleus due to secondary collisions of low energy pions produced in this η-region.

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