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Angular Correlations of Particles Emitted in Nucleus-Nucleus Interactions at 4.5 A GeV/c

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Abstract

The results of the study of two - particle correlations between the spatial emission angles of the secondary particles have been presented. The correlations in the transverse plane of the collission (between the azimuthal angles) have been discussed. The two particles correlation function has been investigated for shower particles in the rapidity space.

1 Introduction:

The motivation of studying high energy nucleus-nucleus interaction is to learn about the space-time development of high-energy reactions within very small distances and short time from impact. At very high energies, the projectile does not have a chance to terminate an interaction with a nucleon before it starts to reach with another. This should produce an intensive mixing of color degrees of freedom of nucleons forming a quark-gluon plasma (QGP) domain or clusters. The decolouring process needs certain time during which an intermediate system may be formed. This hadronic excited cluster may collect target nucleons in its way inside the nucleus, which leads to observation of baryonic clusters in the process of target nucleus destruction (Ahrar, Zafar \& Shafi, 1986). The study of correlation effects in heavy-ion collisions at high energies (Bannik et al., 1986; Nagamiya , 1983 \& Chernov et al., 1984) gives valuable information about the mechanism of interaction forming a multiparticle production and a hot nuclear matter. In this paper we study the distributions of angle intervals of shower and grey particles emitted from the interactions of 4.1A GeV/c ^{22}Ne and 4.5A GeV/c ^{12}C and ^{28}Si with emulsion (Em) nuclei. A comparison between these experimental distributions and the corresponding independent particle emission (IPE) distributions was done. The study of two particle correlations between the spatial emission angle θ of the produced particles for the same interactions is also analyzed.

2 Experimental Techniques:

Nuclear emulsion stacks of the type Br-2 were exposed to different projectiles (4.1A GeV/c ^{22}Ne and 4.5A GeV/c ^{12}C and ^{28}Si beams) at the Dubna Synchrophasotron. The pellicles have dimensions of 20 cm x 10 cm x 600 μm (undeveloped emulsion) . The beam flux was about 10^4 particles / cm^2 and its diameter was about one centimeter. Along the track scanning was carried out. All charged secondary particles have been classified, according to the velocity β = v/c, the range L in the emulsion and the relative ionization $I^* = I/I_o$ where I is the particle track ionization and I_o is that for a singly charged relativistic shower track in the narrow forward cone of an opening angle $\theta \leq 3^o$ (El-Naghy et al.,1994). The groups of particles are: shower (s) particles having $I^* \leq 1.4$ ($\beta \geq 0.7$), grey(g) particles, having $I^* > 1.4$($0.3 \leq \beta < 0.7$),and L> 3 m, these are charged recoil nucleons and black(b) particles, having $L \leq 3$ mm ($\beta < 0.3$), these are slow nucleons and nuclear target fragments .

The sum of b and g particles is called heavily ionizing tracks producing particles " h-particles". The determination of the momentum of s-particles emitted within $\theta \leq 3^o$ enables the separation of produced pions from the non-interacting single-charged particle fragment [16]. The grey particles emitted within $\theta \leq 3^o$ and having L>2 cm are considered to be projectile fragments having Z=2 . The b-particles of $\theta \leq 3^o$ and L>1 cm are due to projectile fragments having $Z \geq 3$. Thus all the particles have been adequately divided into projectile fragments ; target fragments and the generated shower particles (El-Naghy et al., 1994).

3 Results and discussion

To search for hadronic clusters we can use the quantitative method of pseudorapidity intervals $\Delta\eta$. For this purpose the pseudorapidity $\eta = -\ln \tan(\theta/2)$ was calculated for each shower particle produced in 4.1A GeV/c ^{22}Ne-Em and 4.5A GeV/c ^{12}C-and ^{28} $\Delta\eta$ method, the η distribution should be uniform in the studied range of η. In the present work, the η-distribution was found to be flat, within experimental errors, in the range of η = 1-2. This enable us to use the quantitative method of $\Delta\eta$ in the given range, where

$$\Delta\eta^{k}_{ij} = \eta_i \quad \eta_j \qquad (1)$$

The quantity $\Delta\eta^{k}_{ij}$ means the pseudorapidity interval between the i-th and j-th particles such that k particles are laying between them.

$$i \neq j \ ; \ i, j = 1,2 \qquad 0,1 \qquad 2$$

The values of η were rescaled in each event such that

$$\eta_i = (\eta_i - \eta_{min}) / (\eta_{max} - \eta_{min})$$

Taking values from zero to unity, where η_{min} and η_{max} are the minimum and maximum values of η in the considered event.

If the shower particles are emitted independently and no correlations exist between them, their $\Delta\eta$-distribution will have a binomial shape, so that the independent particle emission (IPE) $\Delta\eta$-distribution is given by

$$dN^{n}_{k}/d\Delta\eta = C^{k}_{n-1} \quad \Delta\eta^{k} (1 - \Delta\eta)^{n-k-1} \qquad (2)$$

Where $C^{k}_{n-1} = (n-1)! / k! (n-k-1)!$

The normalized $\Delta\eta$- distributions were obtained for different values of n and k. A deviation between the positions of maxima of the experimental $\Delta\eta$-distribution and the IPE one was observed. Figures (1a, b and c) were selected for presentation to illustrate this deviation for ^{22}Ne- ,^{12}C ^{28} , respectively. From these figures, it is seen that the experimental $\Delta\eta$-distribution (histogram) is shifted to the left, i.e. to lower values of $\Delta\eta$ with respect to the IPE one (solid curve). This is indicates a correlation between the emitted shower particles in the considered interval which may be interpreted as a formation and a subsequent decay of a big hadronic cluster during the multiple production process. This consistent with the formation of excited hadronic cluster, which acquires greater size while moving inside the target nucleus (Kalinkin, Cherbu\& Shmonin, 1979). To investigate whether the motion of hadronic cluster inside the target nucleus is accompanied by a baryonic one, which may be, formed from the target nucleus nucleons (Ahrar, Zafar \& Shafi, 1986), the same mathematical method utilized in searching for hadronic cluster was used. So for each event we defined the azimuthal angle intervals $\Delta\Phi^{k}_{ij}$ for grey particles putting Φ in eq.(1) instead of η, making sure that the ϕ-distribution of grey particles is uniform. The IPE $\Delta\Phi$-distribution is obtained according to eq. (2). Figures (2a, b and c) show the experimental azimuthal angular intervals $\Delta\phi_g$-distributions for grey particles together with the corresponding IPE ones for the previously mentioned interactions. From these figures, it is observed that there is a shift of experimental $\Delta\phi_g$- distributions to the left from that of IPE one. This indicates the existence of strong correlation between grey particles which may be due to the formation of baryonic cluster which is consistent with the previous data (El-Naghy, 1994).

Also the two particle correlation can be investigated using the normalized two-particle correlation function,

$$R_2(\eta_1, \eta_2) = [\rho_2(\eta_1, \eta_2) / \rho_1(\eta_1)\, \rho_1(\eta_2 \quad 1$$

Where $\rho_1(\eta) = (1/\sigma_{inel})\, d\sigma / d\eta$, $\quad \rho_2(\eta_1, \eta_2) = (1/\sigma_{inel})\, d^2\sigma / d\eta_1 d\eta_2$

and ρ_1 and ρ_2 are the single - and two - particle densities, respectively. Practically, $R_2(\eta_1, \eta_2)$ can be obtained from the counted number of single particle and the number of particle paris as

$$R_2(\eta_1, \eta_2) = [N_{inel} N_2(\eta_1, \eta_2) / N_1(\eta_1) N_1 (\eta_2 \quad 1$$

Where N_{inel} is the total number of events in the sample, $N_1(\eta_1)$ and $N_1(\eta_2)$are the total number of particles of $\eta_1$and η_2, respectively, for all events, $N_2(\eta_1, \eta_2)$ is the total number of particle pairs with one particle at $\eta_1$and other at η_2 in the same event, summed over all events. A non-zero value of R_2 means that the particles considered are correlated. Figure (3) represents the dependence of $R_2(\eta_1, \eta_2)$ on η_1 for ^{22}Ne- , ^{12}C- and ^{28}Si-Em interactions, while Figure (4) shows the dependence of $R_2(\eta_1, \eta_2)$ on $(\eta_1 - \eta_2)$ for the same interactions. From Figures(3,4) it is seen that there is a relatively strong correlation at lower values of pseudorapidity. At higher values of the rapidity this correlation disapears.

4 Conclusions:

From the study of the interactions of ^{22}Ne, ^{12}C and ^{28}Si with emulsion at 4.1-4.5A GeV/c, one may conclude that , a strong correlation has been observed in the pseudorapidity distribution for shower particles. A similar correlation has been observed in the azimuthal angle distribution for grey particles. These correlations may indicate to the formation and the subsequent decay of big hadronic and baryonic clusters. This interpretation is consistent with a physical picture in which a hetrophase state of hadronic and quark-gluon plasma has been formed during the collisions of heavy ions with nuclei at high energies. The formation of a big baryonic cluster may explain the phenomenon of complete destruction of heavy target nuclei . The two particle correlation function, in the rapidity space, is positive except in the projectile fragmentation region, i.e. the most forward region (at high values of pseudorapidity).

References

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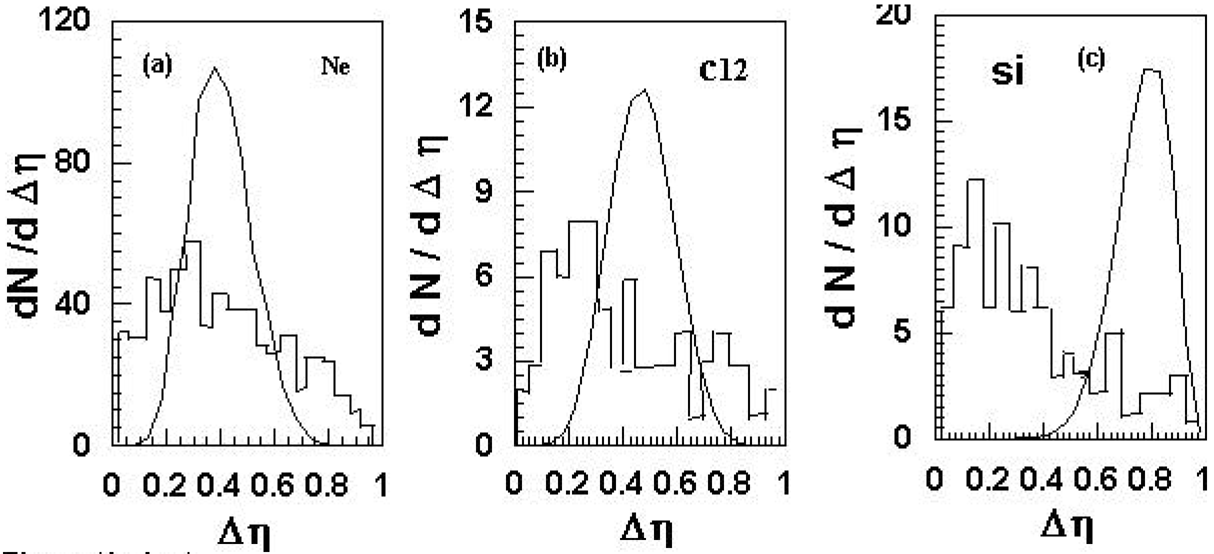
Figure Captions

Figure 1: The $\Delta\eta$-distributions for the interactions of : a) 4.1A GeV/c ^{22}Ne + Em for k=5, n =16, b)4.5A GeV/c ^{12}C +Em for k = 7, n = 16 and c) 4.5A GeV/c ^{28}Si Em for k = 12 , n = 16.

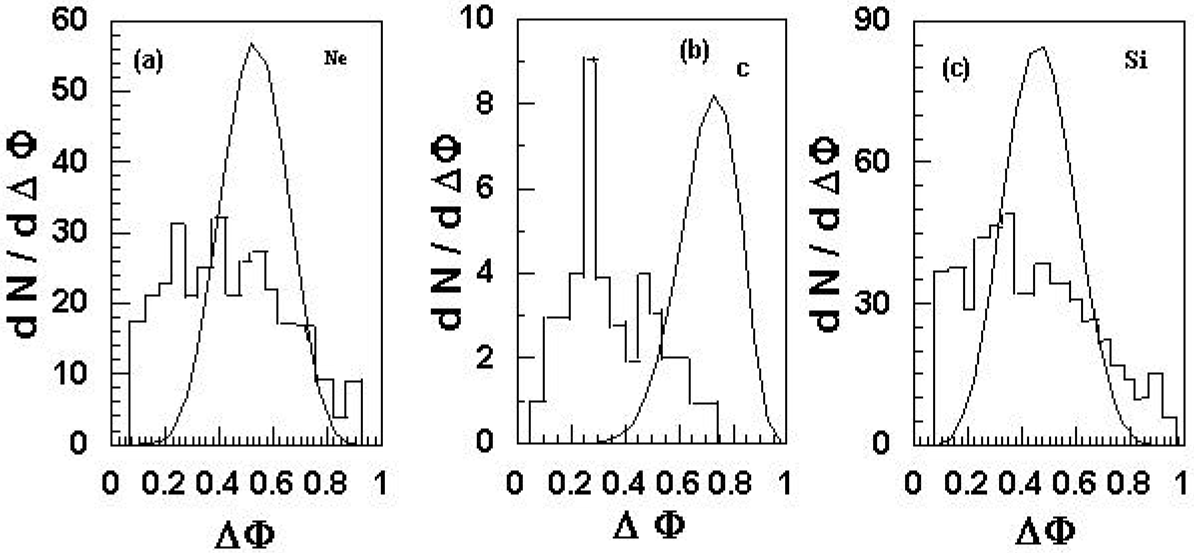
Figure 2: The $\Delta\phi_g$- distributions for the interactions of : a) 4.1A GeV/c ^{22}Ne + Em for k=8, n =16, b)4.5A GeV/c ^{12}C +Em for k = 11, n = 16 and c) 4.5A GeV/c ^{28}Si +Em for k = 8 , n = 16.

Figure 3: The correlation function $R_2(\eta_1, \eta_1 = \eta_2)$as a function of η_1 for the interactions of 4.1A GeV/c ^{22}Ne O , 4.5A GeV/c ^{12}C •, and ^{28}Si ∇ with emulsion nuclei .

Figure 4: The correlation function $R_2 (\eta_1, \eta_2)$ as a function of $(\eta_1 - \eta_2)$ for the interactions of 4.1A GeV/c ^{22}Ne O, 4.5 A GeV/c ^{12}C •, and ^{28}Si ∇ with emulsion nuclei



Figure(1a,b,c)



Figure(2a,b,c)

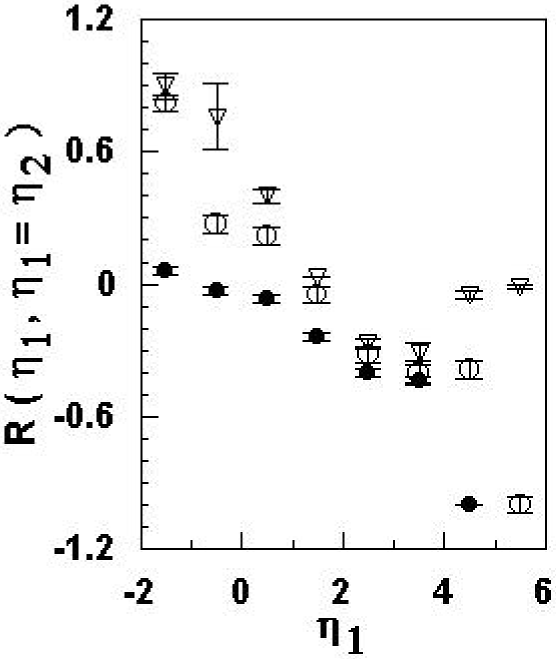
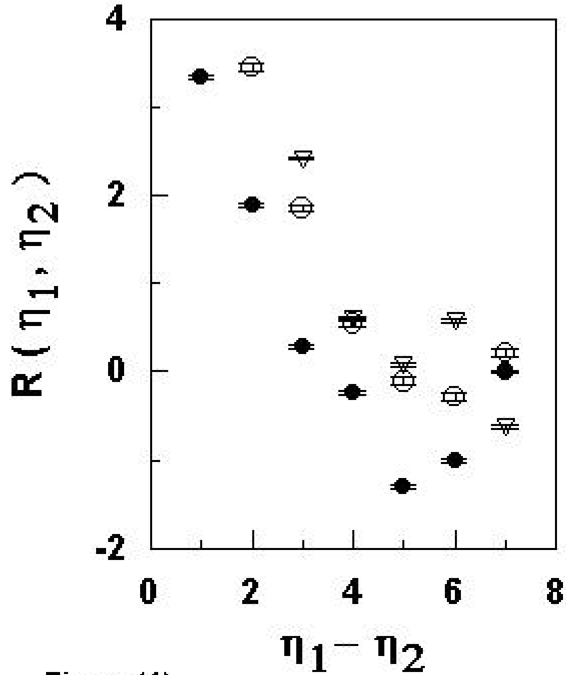


Figure (3)



Figure(4)