Study of Multiplicity Correlations of Various Types of Secondaries in High Energy Nucleus - Nucleus Collisions

M.K.Hegab, N.M.Hassan and Az.E.Ahmed
Physics Department, Faculty of Science, Cairo University, Cairo, Egypt.

Abstract

Multiparticle production and multiplicity correlations, in high energy nucleus-nucleus (AA) collisions are studied in the framework of some theoretical models which consider the collision geometry as a main ingredient. The impact parameter dependence of the number of participants from both nuclei, the number of binary collisions, the number of grey particles Ng, and the total stripping projectile charge Q, are investigated. The impact parameter dependence of the shower particle multiplicity ns is studied in the framework of the superposition model of independent nucleon-nucleus collisions, considering Ng and Q as target and projectile sensors respectively. A comparison is carried out between the correlations of ns, with Ng and Q. The correlation between ns and Q is found to be more sensitive to the collision geometry. The mean ns in AA collisions agrees perfectly well with the (NA) superposition model and the energy dependence is all absorbed in the <ns> of NN collisions.

1 Introduction:

In AA collisions, the multiparticle production depends, in principle, on the degree of overlap between the interacting nuclei (Cheng, 1993). Theoretically the collision geometry is determined by the impact parameter b. In high energy AA collisions, the measurable quantities which are most often used for event classification, are: the total stripping charge Q of spectator projectile (called the projectile sensor), the multiplicity of the target associated fragments N_h and the number of grey particles Ng (the fast target particles in hA events). Nh and Ng are considered as target sensor for the interaction geometry. In the present, work we shall, investigate the theoretical dependence of the various physical quantities in AA collisions, on the impact parameter and their ability to reproduce their experimental correlations with the shower particles multiplicity n_s.

2 Theoretical Models

2.1 Participants and Binary Collisions

The starting theoretical tool in studying AA collisions is the Glauber multiple scattering theory (Hegab,1990),(Franco,1978) in which the total inelastic AA cross-section is given by

$$\begin{aligned}\sigma_{A_p A_t} &= \int d\vec{b}\{1-\exp[2\,\mathrm{Re}\, i\chi_{op}(\vec{b})]\} \\ &= \int d\vec{b}\{d\vec{s}\,'_j\}\left|\psi_p(\{\vec{s}\,'_j\})\right|^2\{1-\exp[2\,\mathrm{Re}\, i\chi_{A_p}(\{\vec{b}_j\})]\}\end{aligned} \tag{1}$$

Where $\psi_p(\psi_t)$ is the projectile (target) wave function. The transmission, $1-\exp(2\,\mathrm{Re}\; i\chi_{Ap})$, is the probability that at least one of the projectile nucleons will interact. The partial cross section $\sigma(A_p, N_p)$

$$\sigma(A_p, N_p) = -\binom{A_p}{N_p}\sum_{j=0}^{N_p}(-1)^j\binom{N_p}{j}\sigma_{A_p-N_p+j} \tag{2}$$

where $\sigma_l = \int d\vec{b}\left\{1-\exp\left[2\,\mathrm{Re}\, i\chi(\vec{b}, l)\right]\right\}$ (3)

The distribution of projectile participant is given by,

$P_{Ap}(N_p) = \sigma(A_p, N_p)/\sigma_{ApAt}$

The distribution for the BC s at a given impact parameter b (Bialas ,1976) is

$$P_{BC}(\nu, \vec{b}) = \binom{A_p A_t}{\nu}\left\{1-D(\vec{b})\right\}^{A_p A_t-\nu}\left\{D(\vec{b})\right\}^{\nu} \tag{4}$$

where $D(\vec{b}) = \sigma_{NN}\int d\vec{s}\, T_p(\vec{b}-\vec{s})T_t(\vec{s})$ (5)

The average number of $BC, \bar{\nu}_{BC}(\vec{b})$, at a given impact parameter, is thus

$$\bar{\nu}_{BC}(\vec{b}) = \sum_{\nu=1}^{A_p A_t}\nu\, P_{BC}(\nu, \vec{b}) = A_p A_t D(\vec{b}) \tag{6}$$

2.2 Shower particles multiplicity

In the present work will treat the AA collision as a superposition of individual NA collisions. So that the mean value of the newly produced particles in AA collisions (Hegab,1990),(Albrecht,1988) is; $\langle n\rangle_{AA} = \langle n\rangle_{NA}\langle N_p\rangle$ where $\langle N_p\rangle$ is the mean number of interacting projectile nucleons and $\langle n\rangle_{NA} = \langle n_1\rangle(1+\langle\nu\rangle)$ is the mean number of produced particles in an NA collisions, $\langle\nu\rangle$ is the average number of collisions in an NA interaction, and $\langle n_1\rangle$ represents the average number of newly produced particles emitted from a single source. The latter is half the average value of produced particles in an NN inelastic interaction at the same specified incident energy /nucleon.

2.3 The grey particles multiplicity (target sensor)

In AA collisions the role of cascading is important. According to the model

(Hegab,1990), the impact parameter dependence of the mean grey particles is,

$$\overline{N}_g\left(\vec{b}\right) = \overline{M}\left(\vec{b}\right)\left\langle N_g\right\rangle_{NA} \tag{7}$$

Where $\overline{M}$ is the mean number of interacting projectile rows at a given impact parameter $\vec{b}$ and may be calculated as $\overline{M}\left(\vec{b}\right) = A(\vec{b})/\sigma_{NN}$ where $A\left(\vec{b}\right)$ is the overlap (interaction) area on the impact parameter plane

2.4 The total charge of projectile spectators Q (projectile sensor)

The mean total charge of projectile spectators at a given impact parameter can directly be calculated by subtracting the mean number of interacting projectile protons, $(Z_P / A_P)\overline{N}_p\left(\vec{b}\right)$, from the total incident charge Zp

$$\overline{Q}\left(\vec{b}\right) = Z_p - \frac{Z_p}{A_p}\overline{N}_p\left(\vec{b}\right) \tag{8}$$

3 Results and Discussion

Figs.(1.a-b) show the calculated N_{PT} as a function of $\vec{b}$ (solid curve), for the interactions of ^{16}O, with the light (CNO) and heavy (AgBr) groups of emulsion nuclei (similar results are obtained for C, Ne & Si projectiles). The number of participants is a maximum for the pure central collisions. The figures also show the dependence of the number of binary collisions ν_{BC} on the impact parameter (dashed curves) for the same above nuclei. It is noticed that ν_{BC} exceeds N_{PT} in the central region, whereas in the peripheral region their roles are reversed. Fig.(2.a-b) represent the correlation of $\overline{n}_s$ with the target sensor N_g for the interactions of ^{22}Ne and ^{28}Si in nuclear emulsion at 4.5 AGeV/c. We notice that, although the calculated curve follow the same trend on the experimental data, deviations appear at the large N_g values. This may imply that some improvements should be done on the applied simple model for N_g production. In addition, eclipse effects which are neglected in the present work, are known to affect appreciably the number of participants, especially in the central events. The correlation of $\overline{n}_s$ with the projectile sensor Q is presented in Figs.(3.a-b) for the interactions of ^{22}Ne and ^{28}Si with emulsion nuclei at 4.5 A GeV/c incident energy. We notice that, except for Q = 0 the calculated curves for all cases follow satisfactorily the experimental data over the whole ranges of Q. The deviation seen at Q = 0 is attributed partly to the negligence of the eclipse effects.

References

Cheng - Shing Wang and Kan- Zhu Guo, Phys. Rev.C (1993) 48,379.
Hegab M.K., Hussein M.T.and Hassan N.M., Z. Phys. A (1990) 336, 345.
Franco V.and Varma G.K., Phys. Rev.C (1978) 18,349.
Bialas A, Bleszynski M.and Czyz W.Nucl. Phys.B (1976) 111, 461.
Hegab M.K., Hussein M.T.and Hassan N.M., J. Phys. G (1990) 16, 607.

Albrecht R.et al., Phys. Lett. 202B (1988) 596. (WA 80 Collaboration).
Hegab M.K. et al., Dubna rapid Comu. No. (1990)7, 36.

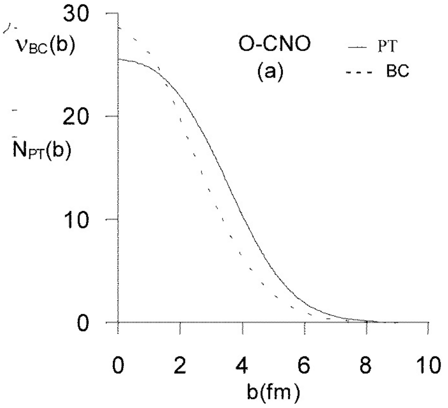

Fig.(1-a)

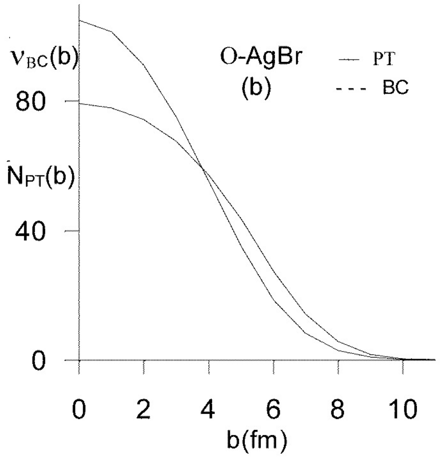

Fig.(1-b)

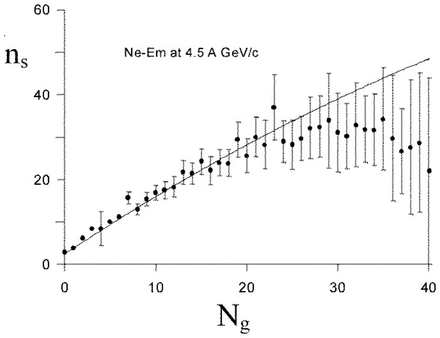

Fig.(2-a)

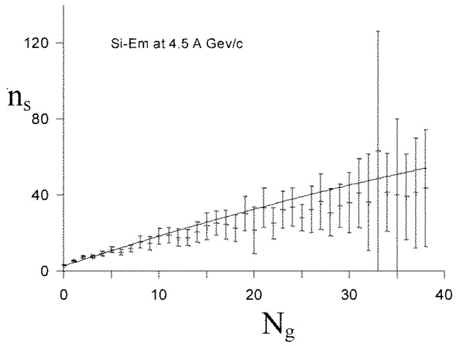

Fig.(2.b)

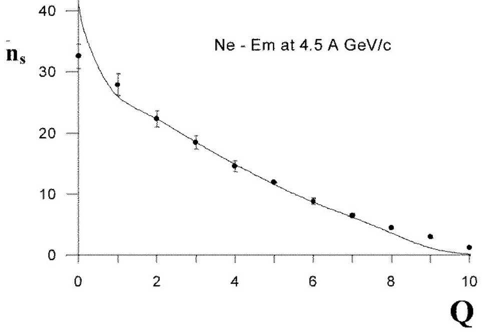

Fig.(3-a)

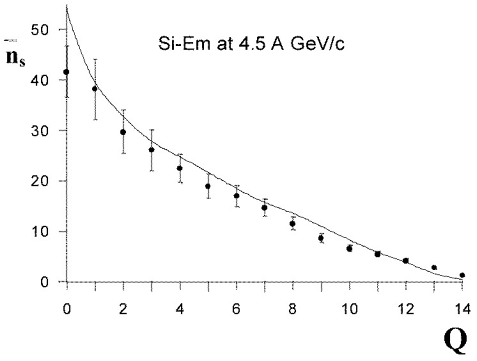

Fig (3-b)