Method for the Characterization of Central Collisions in Nuclear Emulsion Experiment

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Introduction

When a high-energy projectile collides with a nucleus, a number of energetic charged and uncharged particles are produced. The emergence of these fast particles known as shower and grey particles in the nuclear emulsion occurs in a very short time after the impact of the projectile. Grey particles, which are emitted from the target nucleus, are mostly the recoil protons with an admixture of low energy pions. After the emergence of fast particles, the nucleus remains excited for a long time on nuclear time scale. Finally, the residual nucleus de-excites resulting in the emission of a large number of nucleons and other heavier fragments. The process is known as nuclear evaporation process. The particles emitted through this process are generally characterized by black tracks in emulsion except for a very few which may appear as grey tracks. In addition to these particles, projectile fragments (PFs) along the direction of the projectile carrying a single or more charges ($Z \geq 2$) are also emitted. These projectile fragments are also called the spectator or non-interacting fragments. The quantity, Q, which measures the total charge of the non-interacting projectile fragments for inelastic interactions, is defined as: $Q = \sum_f n_f Z_f$ (1)
where n_f is the number of the projectile fragment with charge $Z_f \geq 1$ in an event and summation is carried out over all such fragments in an event. The value of Q characterizes the volume of the non-overlapping part of projectile nucleus. Thus this quantity in nucleus-nucleus collisions enables us to estimate the effective number of the projectile nucleons interacting with the target nucleus, which has been given by the following relation [1]: $<\nu_p> = A_p - (A_p / Z_p)Q$ (2)
where A_p and Z_p are respectively the mass number and atomic number of the projectile nucleus. For ^{28}Si and ^{12}C projectiles the above relation reduces as:
$<\nu_p> = 28 - 2Q$ and $<\nu_p> = 12 - 2Q$ (3)

The values of average number of shower particles per interacting projectile nucleon, i.e., $<N_S>/<\nu_p>$ have been calculated for collisions with H, CNO, AgBr and emulsion targets for our data along with other results at the same energy are presented in Table 1. Following features may be noted from the table.

(i) The average multiplicity of the produced shower particles, $<N_S>$, increases with the increase of the number of interacting projectile nucleons. This observation indicates the possibility of describing the nucleus-nucleus collisions as a superposition of nucleon-nucleon collisions.

(ii) The values of $<N_S>/<\nu_p>$ show a weak dependence on projectile mass and target mass.

(iii) The values of $<N_S>/<\nu_p>$ are practically constant within the stated errors and these are quite close to the respective values of ($<N_S> - \alpha_A$) for proton-nucleus collisions at the same energy per nucleon, where α_A represents the contribution of leading particle in the interaction due to proton projectile. The reported values of α_A are 0.9 and 0.67 respectively [2] for collisions with H target and emulsion nuclei. However, the same value of α_A has been taken for CNO and AgBr targets.

It is interesting to study the analysis of frequency distribution of events in terms of Q for ^{28}Si and ^{12}C–Em interactions at 4.5A GeV. The distributions for our data and for ^{28}Si–Em interactions at 3.7 and 14.6A GeV [3,4] respectively are displayed in Fig.1. The same trend can be seen in the figure. The examination of the distribution shown clearly indicates that the distributions of total charge of non–interacting PF 'Q' are independent of projectile energy. Adamovich et al [5] for ^{16}O -Em interactions at 200A GeV have also obtained similar results. In order to check the effects of impact parameter in terms of N_h on the total charge of the projectile fragment of $Z \geq 1$, the distributions in different N_h intervals are plotted in Fig. 2 (a-c). From Fig. 2 (a) it can be reported that the major contribution is obtained towards the high values of Q in case of N_h = 0,1 (i.e., quasi-nucleus events). A prominent peak is observed in case of N_h – interval of $2 \leq N_h \leq 7$ for larger values of Q. The yield of the distribution increases with the net charge of the spectators, Q, which is supposed to be connected with the gentle low temperature processes, while the yield shows a decreasing trend with Q in case of $N_h \geq 8$ (Fig. 2 (c)), which characterizes the violent high-temperature processes. Similar results have also been reported by other workers [1-5].

Table 1.Values of <N_S> per interacting projectile nucleon in nucleus-nucleus collisions and mean shower projectile multiplicity without leading particle contribution in proton-nucleus collisions for different targets at the same energy.

Target / Projectile	**<N_S>/<ν_p> and (<N_S> - α_p)***				
	H	**CNO**	**Em**	**AgBr**	**Ref.**
^{12}C	0.72 ± 0.08	0.94 ± 0.04	1.05 ± 0.03	1.13 ± 0.05	Present work
^{14}N	0.80 ± 0.08	0.90 ± 0.04	1.02 ± 0.03	1.07± 0.03	(5)
^{24}Mg	0.63 ± 0.09	0.82 ± 0.06	1.10 ± 0.04	1.04 ± 0.04	(32)
^{28}Si	0.71 ± 0.03	0.99 ± 0.03	1.08 ± 0.03	1.24 ± 0.03	Present work
^{28}Si	0.64 ± 0.08	0.80 ± 0.06	0.94 ± 0.04	1.10 ± 0.07	(32)
^{32}S	0.71 ± 0.08	0.71 ± 0.04	0.96 ± 0.03	0.86 ± 0.04	(2)
P*	0.71 ± 0.05	0.91 ± 0.07	0.99 ± 0.05	1.04 ± 0.08	(1)

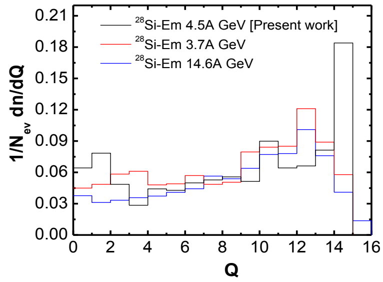

Fig. 1: The overall distribution of events with a given value of Q at different energies.

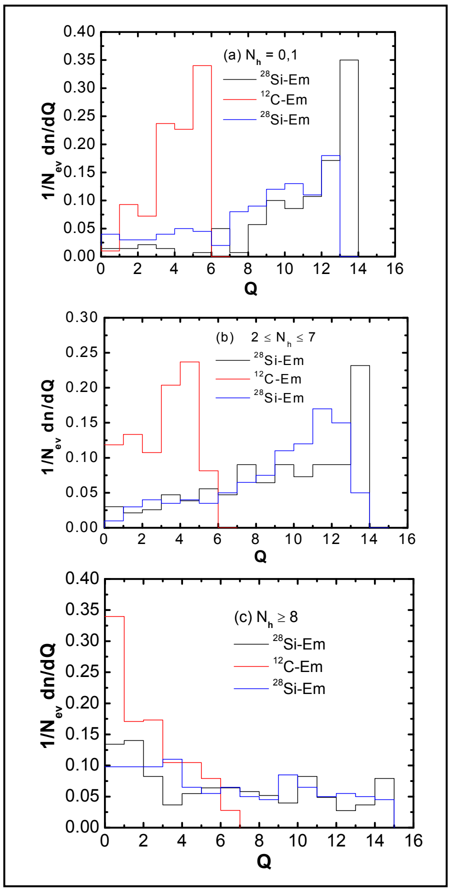

Fig. 2: The distribution of events with a given value of Q for (a) N_h = 0,1 (b) $2 \leq N_h \leq 7$ and (c) $N_h \geq 8$.

References

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