Energy dependence Study of shower production in $^{84}Kr_{36}$ emulsion interactions and in Coulomb modified Glauber Model

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Introduction

The study of relativistic nucleus-nucleus (AA) and nucleon-nucleus (hA) collisions are subject to be of great importance. Such studies may reveal the new phase of matter called QGP. In such collisions, colliding nuclei compresses the nuclear matter up to the extreme limits as a results final state particles production and system may expand and dissembled into mutifragments. Multifragmemtaion process is speculated because excited nuclear system may carry information about equation of state and liquid – gas phase transition of nuclear matter. The photographic nuclear emulsion detector is very useful in the studies of multifrgamentation and it provides good spatial resolution with excellent charged particle detection [1]. Along with the investigation of multifragmentation, the center of attraction in heavy-ion interactions is the total reactions cross-section. Since this reaction cross section, one can extract information about nuclear properties such as nuclear size, neutron and proton density distribution inside the nucleus. The Coulomb Modified Glauber Model (CMGM) is a convenient framework for the calculation of reaction cross at low & high energies; the projectile nucleus is deflected from straight-line path due to the coulomb repulsion called Coulomb Modified Glauber Model [2]. The present work focused on different projectiles such as $^{56}Fe_{26}$, $^{84}Kr_{36}$, $^{132}Xe_{54}$, $^{197}Au_{79}$ and $^{238}U_{92}$ reaction cross section calculated with emulsion nuclei at 1GeV/n in framework CMGM model and those values were used for calculation of total participants, binary collision (B_C) and shower particles (Ns).

CMGM model

According to the Glauber theory, the total nuclear reaction cross-section for nucleus–nucleus (AA) collision can be written as [2, 3]

$$\sigma_R(mb) = 2\pi\int[1-T(b)]b.db. \quad (1)$$

$T(b) = \exp[-\chi(b)]$ is the transparency function and it is calculated from the projectile and target overlap region and the nucleus-nucleus (AA) interaction are given by [3].

$$\chi_{PT}(b) = \chi_{0PT}\exp(-\frac{b^2}{a_P^2 + a_T^2 + r_0^2}). \quad (2)$$

Where

$$\chi_{0PT} = \frac{\pi^2\rho_P(0)\rho_T(0)a_P^3 a_T^3}{10(a_P^2 + a_T^2 + r_0^2)}\bar{\sigma}_{NN}. \quad (3)$$

Nucleon–Nucleus (hA) interaction is obtained by Eq. [3].

$$\chi_T(b) = \frac{\sqrt{\pi}\rho_T(0)a_T^3}{10(a_T^2 + r_0^2)}\bar{\sigma}_{NN}\exp(-\frac{b^2}{a_T^2 + r_0^2}). \quad (4)$$

According to the CMGM, introducing the effect of Coulomb field between the projectiles and target the impact parameter b is replaced by the b´ [3].

$$b' = \frac{\eta + \sqrt{(\eta^2 + k^2 b^2)}}{k} \qquad \eta = \frac{Z_P Z_T e^2}{\hbar v}. \quad (5)$$

These calculated reaction cross-sections used in the calculation of average number of projectile participants (P_{proj}), target participants (P_{targ}) and binary collision (B_C) are according to the Ref [2]. The average number of these values is used in the calculation of shower particles.

Results and Discussions

The energy dependence of the average value of the total nuclear reaction cross-sections [$(\sigma)_R^{theory}$] and along with experimental values are shown in figure 1. Our calculated average value of the nuclear reaction cross-section for projectiles $^{56}Fe_{26}$, $^{84}Kr_{36}$, $^{132}Xe_{54}$, $^{197}Au_{79}$ and

$^{238}U_{92}$ at ~1 GeV/n are compared with $^{16}O_{32}$ projectile of different energies ranging from 0.2 - 200 GeV. The experimental and calculated values for $^{16}O_{32}$ projectile are taken from Ref [3]. One can see from figure 1 that the calculated nuclear reaction cross-section according to the CMGM model for ^{16}O-Em at 0.2 GeV/n and ^{56}Fe-Em, ^{84}Kr-Em and ^{132}Xe-Em at ~1 GeV/n are showing reasonable agreement with the experimental values. The ^{16}O-Em interactions above 2 GeV shows disagreement with the experimental results and at the same time higher mass projectiles such as ^{197}Au-Em and ^{238}U-Em also show disagreement with the experimental values. It indicates that the present CMGM model is not suitable for higher-mass and higher-energy projectiles so further modification should be considered.

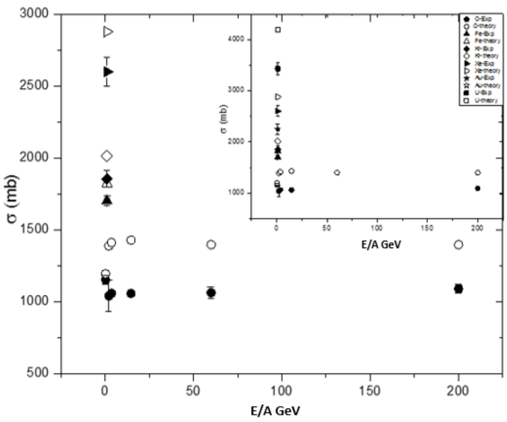

Fig. 1 Energy dependence of the reaction cross-section according to CMGM model for the various projectiles along with experimental values. Inset plot is the zoomed one.

According to the CMGM approaches, we have also calculated the average number of projectile participants (P_{proj}), target participants (P_{targ}) and binary collision (Bc) with different constituents of the emulsion nuclei for different projectiles. The average number of participant's i.e. projectile participants and target participants and binary collisions are used in the calculation of shower (Ns) values with following equation [2].

$$< n_s >_{P-Em} = 2.34 < n_s >_{PP} -4.12. \quad (6)$$

The calculated projectile participants (P_{proj}), target participants (P_{targ}), binary collision (Bc) and shower values are tabulated in table 1. From table 1, one can observe that the calculated value of the shower particles successfully reproduce the experimental values with in the statistical error.

Table 1: The calculated average number of projectile participants (P_{proj}), target participants (P_{targ}), binary collision (Bc) and shower particles values for different projectiles ~1 GeV/n.

Reaction Systems	**<Ns>Exp**	**<Ns> ($P_{pro}+P_{tar}$)**	**<Ns> <Bc>**	**<Ns> Theory**
^{56}Fe+Em	--	21.93	28.44	9.64
^{84}Kr+Em	13.14 ±0.39	28.11	38.64	13.05
^{132}Xe+Em	17.40 ±0.70	30.08	43.66	14.83
^{197}Au+Em	16.43 ±3.43	39.13	60.45	20.24
^{235}U+Em	--	36.11	56.90	19.49

Since the calculated values of participants multiplicity are less than the values of the binary collisions. It indicates that the large number of shower is mainly coming from binary collisions. The average number of produced shower linearly increases with increasing projectiles mass number and incident kinetic energy.

Conclusion

According to the CMGM model, the calculated values of the total nuclear reaction cross-section show satisfactory agreement with the low energy regions and at the same time, it shows disagreement with the higher mass projectiles and high-energy regions. The average number of produced participants, binary collisions and shower particles are dependent on the projectile mass as well as kinetic energy.

References

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