Correlation study of projectile fragment proton with secondary particle multiplicity in $^{84}Kr_{36}$ + emulsion interactions at ~1 A GeV

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The study of projectile fragment (PF) proton, i.e. singly charged, will shed some light on the interface of spectator and participant region. In this paper, we are focusing on correlation between the Z_1 PF and other produced particles.

1. Introduction

Multifragmentation is a fascinating phenomena in the heavy ion collision and it helps to understand the nuclear structure and fragmentation properties. Nuclear emulsion detector has played prominent role in the charge particle detection because of the highest spatial resolution (4π) and excellent relativistic particle detection [1]. Moreover, the emulsion detector not only detects the projectile fragments (PF) but also the target fragments (TF), which is utilized in the analysis of events. According to the participant-spectator model [2], nucleus-nucleus collision has two regions which are called as participant region and rest of the remaining components is the spectator region of target and projectile. The relativistic particles and rare isotopes are formed from the participant region. The target fragments are coming from the target spectators, which is made up of recoil proton and evaporated target's nucleons. The projectile fragments are formed from the projectile spectators. It is speculated because it is coming from the highly excited projectile spectator residue. The projectile fragment proton (N_p) is one of the components of projectile fragment. In the present work, we focussed to study the multiplicity of projectile fragment proton correlated with the secondary particles of $^{84}Kr_{36}$ + emulsion interactions at around 1 GeV per nucleon.

2. Experiment Details

We have analyzed data collected from the scanning of highly sensitive NIKFI-BR2 nuclear emulsion detector's plates having unprocessed thickness of 600 μm. The dimension of emulsion plate was 9.8×9.8×0.06 cm and emulsion plate were horizontally exposed to the $^{84}Kr_{36}$ + beam having kinetic energy ~ 1 GeV per nucleon at GSI Darmstadt, Germany. The interactions are observed through the line scanning method with the Olympus BH-2 transmitted light binocular microscope having objective lens of 100X along with the 15X eyepieces. Through the method, the primary beam tracks were picked up at 5 mm distance from the edge of emulsion plates. To ascertain that we are following primary track, first, we followed the track in the reverse direction till the edge of the emulsion plate. We performed measurements on 892 inelastic $^{84}Kr_{36}$ + emulsion interactions. The secondary particles are classified according to the emulsion terminology as given in the ref. [3].

3. Results and Discussion

Fig. 1 is the correlation between projectile fragment proton's (N_p) multiplicity and secondary particles mean multiplicities $\langle N_h \rangle$, $\langle N_b \rangle$, $\langle N_g \rangle$, $\langle N_s \rangle$, $\langle N_{Alpha} \rangle$ and $\langle N_c \rangle$ for $^{84}Kr_{36}$ + emulsion interactions at ~ 1 A GeV. The experimental data points are fitted with straight line function and those fitting parameter are tabulated in the table1.

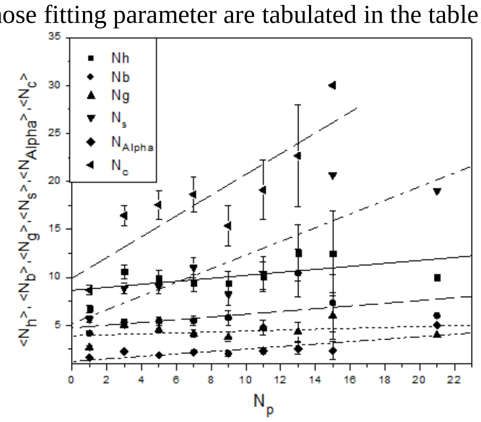

Fig.1: Multiplicity correlation between the N_p and $\langle N_h \rangle$, $\langle N_b \rangle$, $\langle N_g \rangle$, $\langle N_s \rangle$, $\langle N_{Alpha} \rangle$, $\langle N_c \rangle$ for $^{84}Kr_{36}$ + emulsion interactions at ~ 1 A GeV.

From Fig. 1, we can observe that the average compound and shower particles multiplicities show strong correlation with the number of emitted projectile fragment proton (N_p). At the same time, the secondary particles such as black, grey, alpha, and heavy ionizing charged particles have shown weak correlation with the number of emitted projectile fragments proton (N_p). It can also be seen from Fig. 1 that the rate of emission of compound multiplicity with projectile fragment proton is higher than the same for shower particles.

Table 1: The fitting parameter's values are tabulated.

Mean multiplicity	a	b
$<N_h>$	8.64 ± 0.97	0.15 ± 0.08
$<N_b>$	4.72 ± 1.08	0.14 ± 0.09
$<N_g>$	3.91 ± 0.57	0.04 ± 0.05
$<N_s>$	5.19 ± 1.72	0.71 ± 0.15
$<N_{Alpha}>$	1.23 ± 0.38	0.12 ± 0.03
$<N_c>$	9.9 ± 2.3	1.08 ± 0.25

The emission rate of shower particle mean multiplicity shows strong dependence on emitted number of projectile fragment protons. It is well established that the showers are newly produced particles from the participants region of the collision.

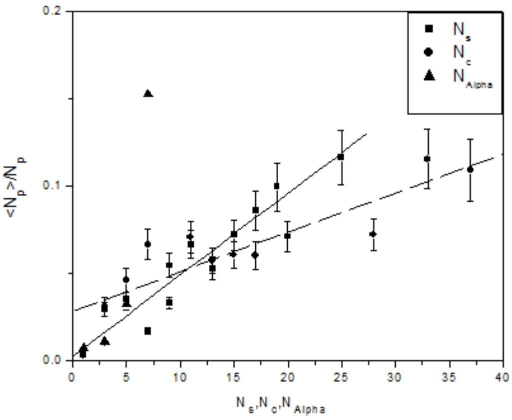

Fig.2: Normalized Multiplicity correlation between the $<N_p>/N_p$ and N_s, N_c, N_{Alpha}.

It seems that the singly charged projectile fragment protons are coming from the inner mono nucleonic surface of projectile's spectator, i.e., from the interface of the spectator-participant region of projectile and target. The normalized multiplicity of projectile fragments proton, i.e., $(1/N_p)*(d<N_p>/dN_i)$ correlated with $N_i = N_s$, N_c, N_{Alpha}, N_h, N_b, and N_g are shown in Figs. 2 & 3. From Fig. 2, we can notice that the number of projectile fragment protons linearly increases with increasing the shower particles and compound particles. The normalized multiplicity of projectile fragment protons remarkably increases with beyond the compound multiplicity $N_c = 28$ in an event.

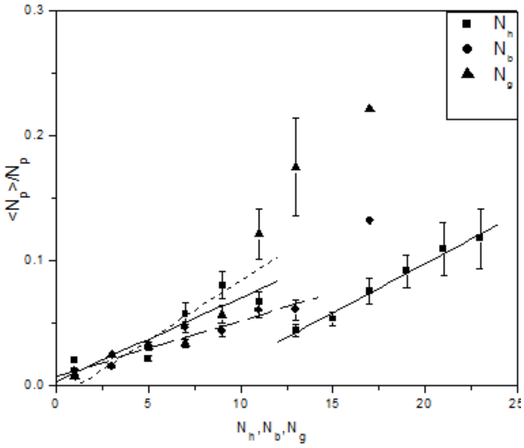

Fig.3: Normalized Multiplicity correlation between the ($<N_p>/N_p$) and N_h, N_b, N_g.

From Fig. 3, it can be seen that the number of target fragments; recoiled target nucleons and their sums (N_b, N_g and N_h) have weaker correlation with the emission of projectile fragment protons (N_p) per event. In the region from 1 to 11 of target fragments, <Np>/Np is increasing linearly. Again the number of heavily ionizing charged particles (N_h) increases linearly with the number of N_p value beyond the 13 N_h per event.

4. Conclusions

In the light of above results, we may conclude that, most of the singly charged projectile fragments are emanating from the interface of participant and projectile's spectator regions. It may also be concluded that singly charged projectile fragments have strong dependence on the size of the interacting target.

5. References

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