Study of $^{84}Kr_{36}$ Projectile Fragments with Compound Multiplicity at ~1 A GeV

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INTRODUCTION

Nuclear emulsion detector (NED) has had a very long track record as particle detector and its importance has been proven through a long list of fundamental discoveries. It consists of H, CNO and silver halides (AgBr), where a latent track is formed after the passage of an ionizing particle. In the nuclear emulsion heavy ion collisions at intermediate and high energies provide to study the properties of nuclear dense matter and extreme conditions. In the last few decades, pions, kaons and recoil nucleons were the focus of the study of hadron-nucleus and nucleus-nucleus collision. These recoil target's nucleons (Grey particles) are in the medium energy (30-400 MeV), and basically these are eject-out target protons and emitted during the passage of leading particles. In the hadron-nucleus and nucleus-nucleus collision at higher energy, the new variable term introduced N_C (= N_g + N_s) that is compound multiplicity. N_C was introduced by Jurak and Linsheid [1], which represents the complete participant region of the colliding nucleus. Our earlier study [2] of participants region with target's fragmentation and their dependency on the energy of the colliding system showed strong dependency on both parameters. Therefore it is important to study the participant region in the light of projectile fragmentation.

EXPERIMENTAL DETAILS

In the present experiment a stack of high sensitive NIKFI BR-2 nuclear emulsion pellicles dimension 9.8×9.8×0.06 cm^3 exposed to $^{84}Kr_{36}$ ion having kinetic energy around 1 GeV per nucleon. The exposure was performed at *Gesellsehaft fur Schwerionenforschung* (GSI) Darmstadt, Germany [2]. The interaction event was found through scanning technique with using an oil immersion objective of 100X magnifications along with 15X eye-pieces. Present study is based on the 448 minimum bias primary inelastic interactions of $^{84}Kr_{36}$ with various nuclear emulsion detector components.

In the nuclear emulsion, secondary particles are classified into four categories such as:

(a) **Black particles**: These are evaporated target fragments and their ranges are 0<3mm and velocities are 0.3c and also their energy less than 26 MeV. The black particles are denoted as N_b.

(b) **Grey particles**: The grey particles mostly recoil protons and their kinetic energy 26 < E < 375 MeV, and also their range must be greater than 3mm. The grey particles denoted as N_g.

(c) **Shower particles:** These are singly-charged, newly created relativistic particles and their velocity greater than 0.7c. These shower particles are mostly charged pions and kaons created in the participants region of the colliding nucleus and denoted as N_s.

An other set of parameter defined as a sum of number of recoiled target fragments or nucleons specially protons and newly created shower (pions and kaons) particles is called compound particles N_c and derived as N_c=(N_g+N_s). Target recoiled protons are not violently participated in the collisions. It means they are basically coming out from the edge of the participant regions not from the core.

Heavily Ionizing charged particles: This set of charged particles representing a group of target fragments, which was at rest before the collisions. The black and grey particles together are called heavy ionizing particle N_h = (N_g + N_b).

Projectile Fragments (PF): The projectile fragments are actually projectile spectators according to the Participants–Spectator Model [3]. In current article, projectile fragment is categorized as singly charged projectile fragment ($PF_{Z=1}$) which are mostly projectile protons, doubly charged projectile fragments ($PF_{Z=2}$) are helium nucleus and multiple charged projectile fragments having charge more than two ($PF_{Z>2}$). All type of projectile fragments having very long constant ionization track length in a narrow forward cone depending on the charge of the projectile fragments.

CHARGE ESTIMATION OF PF

The ionization measurements are useful to estimating the charge of projectile fragments. Different methods are used in earlier but fundamental principle is related to the ionization. When ionization is low, error in such estimation may not be high but the grain density increases. The adjacent grains became unsolvable even under high magnification microscope. In the tracks of heavily charge particles, the grains get clogged to each other to form blobs and it is not possible to count the individual grains. Different methods are using for quantitative measurement, such as 1)Grain Density 2) Blob and Grain Density or Gap Length Coefficient 3) Mean Gap Length 4) Delta Rays 5) Relative Track Width and 6) Residual Range Methods. Single method cannot apply for the entire range (1-36) of charge because every method has limitations [2].

RESULTS AND DISCUSSION

Dependency of participant region and target spectator has been presented in detail in Ref. [2]. Our current study is only focused on the projectile fragmentation and impact on participant region. In this regard, we estimated charges of projectile fragments using grain density for singly charged fragment and blob & grain density measurement for doubly charged projectile fragments, and rest charged fragments considered as heavy projectile fragments having charge more than two units. Error in the estimation of the projectile charge is ±1 unit of charge.

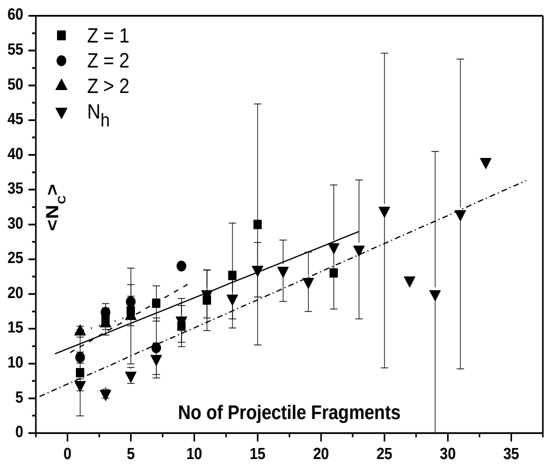

Fig. 1: Correlation between $<N_c>$ with $<Z_1>$, $<Z_2>$, $< Z_{>2} >$ along with $<N_h>$.

Variation of participant region with the emission of projectile fragments i.e. projectile spectator is shown in Figure 1. Data of target fragments (N_h) are overlaid. From the Figure 1 we may see that the recoil target nucleons especially protons and evaporated target fragment are collectively showing strong correlation. Data points are fitted with a straight line function as $<N_c> = m (N_h) + c$ with m equal to 0.81±0.11 and intersection at $<N_c>$ is equal to 7.05±2.14. Same straight line function have been fitted to the number of projectile fragments having charge (Z) equal to 1, 2 and more than 2 with slope 0.75±0.22, 1.06±0.75 and 0.56±0.02, respectively. The intersection of the projectile fragments are 12.13±2.46, 11.37±4.31 and 14.04±0.04 for singly charged, doubly charged and heavy projectile fragments, respectively. The maximum number of projectile fragments emitted in an event is 23, 6, and 6 for Z = 1, 2 and >2 projectile fragments, respectively. The maximum number of heavily ionizing particles (N_h) emitted from the target nucleus per event is 36. From Figure 1, the compound multiplicity gradually increases with increase of the projectile singly charged (Z = 1) spectator. The compound multiplicity nicely correlated with projectile fragments. The correlation between $<N_c>$ and projectile fragments for $^{84}kr_{36}$ emulsion interactions at 1 GeV is shown in Figure 1. From the Figure 1, we may infer that the lighter charge projectile fragments such as Z = 1, and heavily ionizing charged particle i.e. particles associated with target nucleus have similar slopes within statistical error such as 0.75±0.22 and 0.81±0.11, respectively. This indicates that both have similar strength of correlation with participant region i.e. N_C. We may also translate this inference that these nucleons are emitting from nucleons layers nearest to the participant region of collision.

The doubly charged helium nucleus shows stronger correlation with the compound multiplicity than singly charged projectile fragments. It may be inferred that alpha particles are not only coming from one region of the spectator. The heavy projectile fragments having Z>2 has shown weaker correlation with particles coming from participant region. It means heavy projectile fragments are mostly coming from the region least affected by the participant region.

Acknowledgments

Authors are grateful to the all technical staff of GSI, Germany for exposing nuclear emulsion detector with $^{84}Kr_{36}$ beam.

Reference

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