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Projectile multifragmentation study in the interaction of ^{84}Kr with nuclear emulsion detector at relativistic energy

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A heavy-ion collision provides a unique opportunity to study the state of matter under extreme conditions of density and temperature. Nuclear fragmentation is an important experimental phenomenon in nucleus-nucleus collision at relativistic energy, since it carries the information about emission mechanism, phase transition of the nuclear matter as well as equation of state. The interesting feature of heavy-ion interactions is the variation of reaction properties with collision geometry. Multifragmentation is one of the most important aspects of heavy ion collision. This work focus on the emission characteristics of the intermediate mass fragments produced in the interaction of ^{84}Kr with nuclear emulsion at incident kinetic energy of 1 GeV per nucleon.

Keywords: ^{84}Kr-emulsion interactions, Nuclear emulsion detector, Intermediate mass fragments

1 Introduction

The Nuclear Emulsion Detector (NED) has played important role in high energy interaction physics and it is in use from the birth of the experimental nuclear physics[1]. The compactness of size, better position resolution (~1µm) and 4π detection capability makes it a unique detector in experimental nuclear physics[1]. According to the Participant Spectator Model[2] the interacting systems can be divided into three main regions; (i) Projectile spectator region, (ii) Target spectator region, and (iii) Participant region. In the participant region the quark gluon plasma will form at high incident energy while the liquid phase transition occurs in the spectator regions[2]. The momentum transfer in participant region is high compare to the both spectator (projectile spectator and target spectator) regions. Figure 1 shows the schematic view of participant spectator model.

Present work focuses on the emission characteristics of the intermediate mass fragments produced in the interaction of ^{84}Kr with nuclear emulsion at 1 GeV per nucleon.

2 Experimental Details

The data was collected by the scanning of highly sensitive NIKFI BR-2 nuclear emulsion film having dimensions 9.8 × 9.8 × 0.06 cm^3 were exposed horizontally by using ^{84}Kr as projectile at incidence kinetic energy ~1 GeV per nucleon.

The exposures of NIKFI BR-2 nuclear emulsion film were performed at Gesellschaft fur Schwerionen for schung (GSI) Darmstadt, Germany[2,3].

The sketch of the nuclear emulsion detector with incident beam of ^{84}Kr is shown in Fig. 2. The nuclear emulsion detector used in this study is a composite target detector which contains the combination of several nuclei such as H, C, N, O, Ag and Br having very small percentage of S and I. The targets in nuclear emulsion detector are divided into three main combinations such as; (i) light target (H nucleus), (ii) medium target (combination of C, N, and O), (iii) heavy target (Ag and Br)[3]. In the scanning process the beam tracks were picked up at a distance of 4 mm from the edge of the emulsion plate and followed

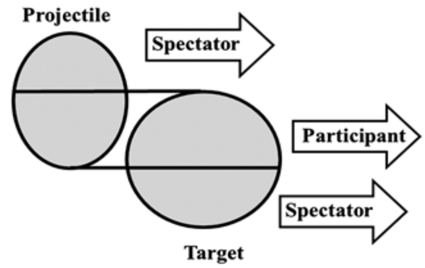

Fig. 1 – The schematic view of participant spectator model.

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carefully until they interacted or escaped from the surface in the emulsion plate. There are two standard scanning methods one of them is line scanning and other one is the volume scanning method. For scanning we have used Olympus BH-2 transmitted light-binocular microscope under 100X oil emersion objectives. The photo of Olympus BH-2 transmitted light-binocular microscope is shown in Fig. 3.

The target fragments are mostly coming from the target spectator regions and are classified based on their range (L), velocity (β) and normalized grain density (g*) in the various types as mentioned below[4];

2.1 Black particles (N_b):

These particles are basically evaporated nucleons from the target spectator region which have L < 3 mm, $\beta < 0.3$ and $g^*>6.0$ [4]. These particles are mostly coming from the target spectator region

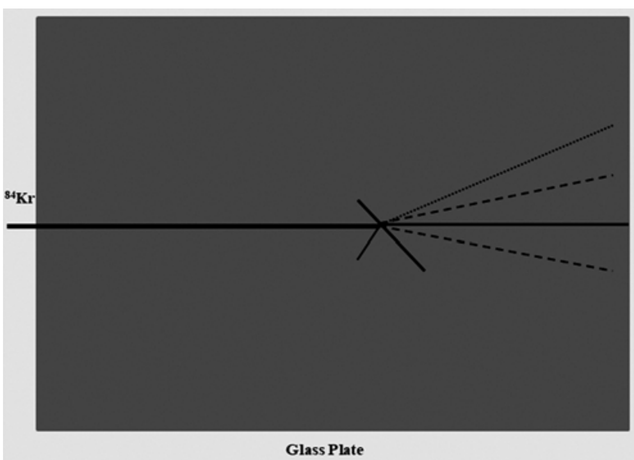

Fig. 2 – The sketch of the incident beam (^{84}Kr) with nuclear emulsion plate[4].

Fig. 3 – Photo of the Olympus BH-2 transmitted light-binocular microscope[4].

2.2 Grey particles (N_g):

These particles are mainly recoiled target nucleons which have L > 3mm, $0.3 \leq \beta < 0.7$ and $1.4<g^*<6.0$ [4]. As like black particles these particles are also coming from the target spectator region

2.3 Heavily ionized charged particles (N_h):

These are the sum of black particles (N_b) and grey particles (N_g). The separation of different target groups are based on the N_h values. For AgBr target group the value of N_h is more than 8 and for CNO target group it will in the range of 2 to 8, while for H target group it will be 0 or 1 [3].

2.4 Shower particles (N_s):

These particles are mostly produced in participant regions and have $\beta > 0.7$ and $g^*<1.4$ [4].

The projectiles fragments are classified into three main categories; (i) singly charge projectile fragments ($N_{Z=1}$), (ii) doubly charge projectile fragments ($N_{Z=2}$), and (iii) multiple charge projectile fragments ($N_{Z\geq3}$), it includes the intermediate and heavy charge projectile fragments [4].

3 Results and Discussion

The study of multi-fragmentation is one of the important parameters in heavy-ion collision physics[5,6]. It reveals the information about the decay of the highly excited nuclear system, which carries the information of phase transition and equation of state of matter[5,6]. When a nucleus excited beyond its total binding energy it will decay into various intermediate mass fragments (IMF). The emission characteristic study of intermediate mass fragments provides the information of reaction mechanism of the nucleus-nucleus collisions[5,6]. The sum of the entire projectile fragments which have charge $Z \geq 2$ of an event are known as bound charge and it is represented as Z_{bound}.

Figure 4 shows the variation of average multiplicity of intermediate mass fragments ($<N_{IMF}>$) with respect to bound charge (Z_{bound}) for ^{197}Au at 10.6 A GeV [7], ^{84}Kr at 1 A GeV [Present work]. From Fig. 4 we can see that the peak position is different for different projectiles. We have studied this physics for same projectile having different incident kinetic energy, as well as different projectile at relativistic incident kinetic energy [6,9]. From the study we concluded that due to the production of higher charge

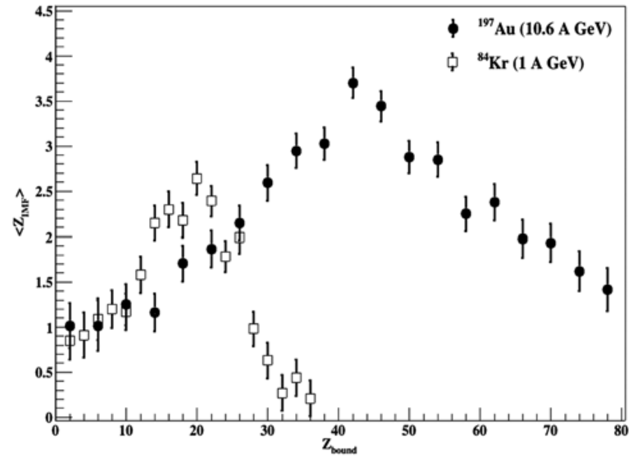

Fig. 4 – The variation of the average multiplicity of intermediate mass fragments as a function of Z_{bound} for ^{197}Au at 10.6 A GeV [7] and ^{84}Kr at 1 A GeV [Present work].

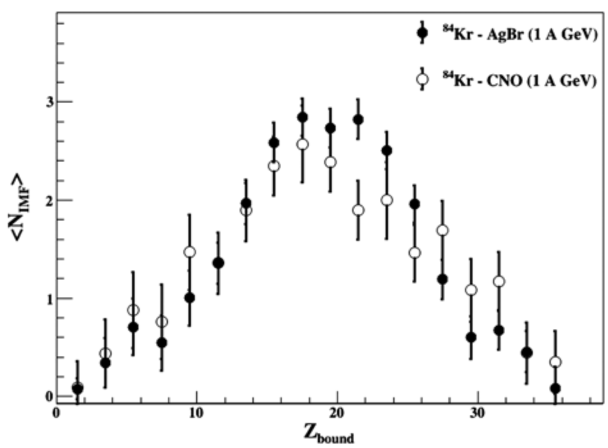

Fig. 5 – The distribution of $\langle N_{IMF} \rangle$ as a function of Z_{bound} for the interaction of the ^{84}Kr at 1 A GeV with AgBr target group and CNO target groups [Present work][9].

fragments as well as the law of charge conservation the peak locations and overall distribution of $\langle N_{IMF} \rangle$ are shifted to lower value for low energy data and higher value for higher energy data [6,9]. Which show that the distribution of $\langle N_{IMF} \rangle$ is depending on the incident kinetic energy of the projectile beam, the results obtained in this analysis are also consistence with other experimental observations [8].

Figure 5 shows the distribution of $\langle N_{IMF} \rangle$ as a function of Z_{bound} for the interaction of the ^{84}Kr at 1 A GeV with AgBr target and CNO target groups of the nuclear emulsion detector[9]. From Fig. 5 it is clear that the maximum values of mean multiplicity of intermediate mass fragments are increases with increasing target mass[9]. Thus the multiplicities of intermediate mass fragments are strongly depending on the mass of the target groups from which the projectile beam will interact during the collisions.

4 Conclusions

This analysis shows that the emission characteristics of the projectile multi-fragmentation reveal the information of the equation of state of matter and of the phase transition. The study of correlation between $\langle Z_{IMF} \rangle$ and Z_{bound} suggests that the distributions of Z_{bound} are depending of the incident energy as shown in Fig. 4. The correlation between $\langle Z_{IMF} \rangle$ and Z_{bound} for different target groups of nuclear emulsion as shown in Fig. 5, shows that the mechanism of multifragmentation of the spectator part of the projectile nucleus depending on the target mass.

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References

1 Barkas W H, *Nuclear Research Emulsion*, Academia Press, London (1963).
2 Singh M K, Soma A K, Pathak R & Singh V, *Indian J Phys*, 85 (2011) 1523.
3 Singh M K, Soma A K, Pathak R & Singh V, *Indian J Phys*, 87 (2013) 59.
4 Singh M K, *V B S Purvanchal University*, Jaunpur (2014).
5 Singh M K, Singh U, Bhatnagar N & Singh V, *Int J Mod Phys E*, 28 (2019) 1950063.
6 Singh M K, Singh V & Bhatnagar N, *J Kor Phys Soc*, 75 (2019) 764.
7 Jain P L, Singh G & Mukhopadhyay A, *Phys Rev C*, 50 (1984) 1085.
8 Debnath B, Talukdar R & Bhattacharjee B, *Indian J Phys*, 82 (2008) 633.
9 Singh M K, Singh U, Gupta B R K, Bhatnagar N & Singh V, *The Eur Phys J Plus*, Accepted (In Press) (2019).