KNO Scaling Analysis of Singly Charged Projectile Fragments at Relativistic Energies

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This research article deals with the KNO scaling behaviour of singly charged projectile fragments emitted during $^{84}Kr_{36}$ interactions with nuclear emulsion detector at around one GeV per nucleon. We observed that singly charged projectile fragments are strongly obeying the KNO scaling behaviour.

1. Introduction

The emission of singly charged projectile fragments (Z=1) is a consequential process of multifragmentation. This process has been under intense study, both theoretically and experimentally. Multifragmentation is a violent reaction and associated with minuscule impact parameter. The singly charged projectile fragments are produced in the violent reaction, so it may carry information about the reaction mechanism, excited nuclear systems and collision dynamics, which is very useful to understand the thermodynamic properties of nuclear systems [1]. In this paper, we thoroughly investigated the emission process of singly charged projectile fragments from $^{84}Kr_{36}$-Emulsion interaction at around 1 A GeV. The singly charged projectile fragments multiplicity has been well explained by the Koba-Nielsen-Olesen (KNO) scaling law with different target and as far as possible; our results are compared with other experimental results.

2. Results and Discussion

The multiplicity distributions of singly charged projectile fragments are a potentially useful source of information about the production mechanism. The multiplicity distributions of singly charged projectile fragments emitted in the $^{84}Kr_{36}$-Emulsion interaction at ~1GeV in terms of probability is shown in Figure 2 and distribution of same according to their emission in various emulsion target groups, in terms of normalized distribution is presented in Figure 1. Each distribution in Figure 1 is fitted with Gaussian function. The width of the distribution is obtained 6.8 and 17.2 for all targets and Ag/Br target group, respectively. It can be inferred from the distribution that the emission of singly charged fragments is slightly dependent on target mass number (A_T). It can also be seen that, the distribution function is almost same for the different target groups of nuclear emulsion detector and the width is increasing with increase in the target mass number.

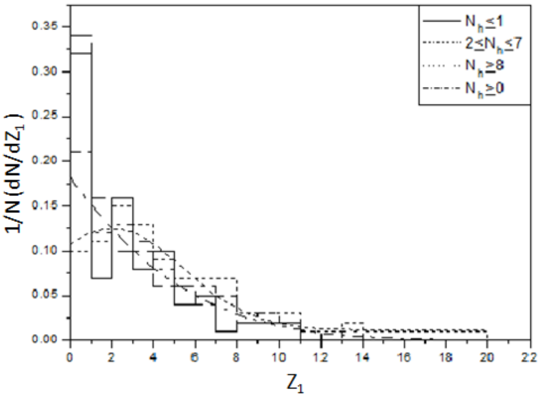

Fig. 1: Normalized Multiplicity distributions of singly charged projectile fragments (Z_1) for $^{84}Kr_{36}$-Emulsion interactions at ~1 A GeV.

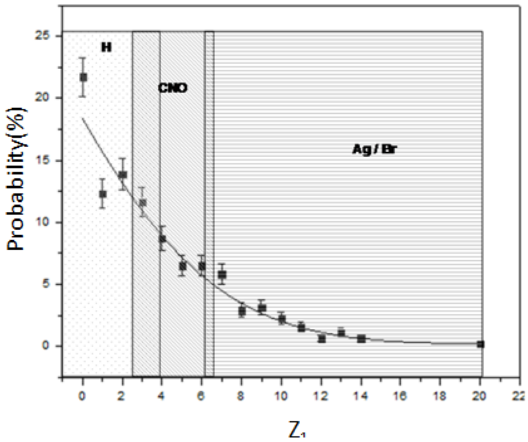

Fig. 2: Probability distribution of the singly charged projectile fragments (Z_1) for $^{84}Kr_{36}$-Emulsion interactions at ~1 A GeV.

Figure 2 shows that the events having no singly charged projectile fragments emitted are most probable, i.e., up to 21.74±2.2 in the present case. The distribution is fitted with Gaussian function and the fitted parameters such as width and peaks values are found to be at 16.28 and -10.07. From figure 2, one can observe the various separated regions and these regions are considered being different target of the emulsion groups. It should be mentions that, in figure 2 different regions are roughly marked up according to the target groups.

3. KNO Scaling

The Koba – Nielson – Olesen (KNO) has been a prominent framework to study the behavior of secondary particles multiplicity distribution in heavy ion collisions. This framework is a consequence of the nuclear geometry and it is originally derived from the Feynman scale of particle production cross section. According to KNO scaling, multiplicity distribution is written as [2]

$$\psi(Z) = 4Z \exp(-2Z). \qquad (1)$$

Where, $\psi(Z) = \langle Z_1 \rangle P(Z_1) = \langle Z_1 \rangle \sigma_{nz} / \sigma_{inels}$. (2)

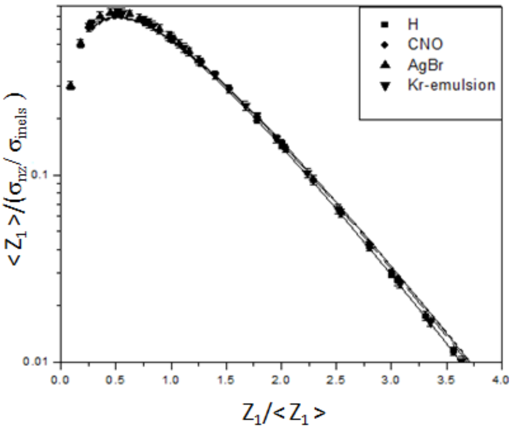

Fig. 3: The KNO scaling distribution of singly charged projectile fragments (Z_1) emitted for the $^{84}Kr_{36}$ + emulsion interactions at ~ 1 A GeV is plotted. The experimental data points are fitted with KNO scaling function $\psi(Z) = AZ \exp^{(-BZ)}$, represented by the solid line.

In figure 3, we plotted $\langle Z_1 \rangle \sigma_{nz} / \sigma_{inels}$ as a function of $Z_1/\langle Z_1 \rangle$ for various emulsion target groups such as H, CNO and Ag/Br as well as emulsion, for the $^{84}Kr_{36}$ - emulsion interactions at ~ 1 A GeV. Here σ_{nz} denotes the partial cross section of singly charged projectile fragments and $Z = Z_1 / \langle Z_1 \rangle * \sigma_{inels}$ represent as the total inelastic cross section. It should be mentioned here that the experimental data points for $Z_1 = 0$ is not included in the distribution.

Table 1: The KNO scaling fitting parameters for ^{84}Kr + emulsion interactions at ~ 1 GeV per nucleon compared with ^{84}Kr + emulsion interactions 1.7 A GeV per nucleon.

Type of event	Energy (A GeV)	A	B	Ref
^{84}Kr - H	1.7	3.28±0.96	2.10±0.24	[3]
^{84}Kr-CNO	1.7	3.00±0.51	1.95±0.13	[3]
^{84}Kr-AgBr	1.7	3.46±0.66	2.08±0.16	[3]
^{84}Kr-Em	1.7	3.36±0.35	2.02±0.08	[3]
^{84}Kr-H	1.0	3.6±0.6	1.93±0.28	PW
^{84}Kr-CNO	1.0	3.7±0.6	1.94±0.28	PW
^{84}Kr-AgBr	1.0	3.6±0.6	1.95±0.28	PW
^{84}Kr-Em	1.0	3.6±0.6	1.93±0.28	PW

Figure 3 depicts the experimental data points completely laid on the universal curve within the experimental error. The best fitting parameter values are obtained from this graph presented in table 1.

4. Conclusions

The obtained values of fitting parameters are more proximate to the theoretical value within the statistical error i.e. A = 4 and B = 2. The value of fitting parameters is compared with the $^{84}Kr_{36}$ + emulsion interactions at 1.7 A GeV. With the help of table 1 and Figure 3, we may infer that the observed results are independent of incident projectile energy and strongly obeying the KNO scaling law.

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