Characteristics of Target Dependence of Clan Model Parameter in $^{84}Kr_{36}$ - Emulsion Interactions at Relativistic Energy

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The paper focuses on study of the clan model parameters and their target dependence in light of void probability scaling for heavy (Ag and Br) and light (C, N and O) groups of targets present in nuclear emulsion detector using $^{84}Kr_{36}$ at around 1 GeV per nucleon. The variation of scaled rapidity – gap (rap-gap) probability with single moment combination has been studied. The average clan multiplicities ($\bar{N}$) for interactions, increases with the pseudo-rapidity interval (Δη) were observed along with other important parameters. The values of for Ag / Br targets are larger than those for CNO target and also average number of particles per clan ($\bar{n}_C$) increases with increase in pseudo-rapidity interval. We further observed that for a particular target, average number of particles per clan ($\bar{n}_C$) increases with an increase in the size of projectile nucleus.

1. Introduction

The search of final state particles produced in nucleon-nucleus or nucleus-nucleus interactions at high energy is the main objective of studying the relativistic heavy ion experiments. The multiplicity distributions reveal crucial issues related to the basic properties of the hot as well as dense medium. In the case of a cascade event any particle produced from a primary cluster named the ancestor [1 - 5]. All of the particles having a common ancestor form a clan. The clans have no mutual interactions, whereas the particles emitted due to disintegration of a particular clan have strong correlations. In the context of clan models the average clan multiplicity $\bar{N}$ and the average number of particles per clan $\bar{n}_c$ are of immense physical importance and are referred to as the clan model parameters.

2. The model

Let $P_n(\Delta\eta)$ be the probability of producing or detecting n number of particles in a pseudorapidity interval Δη. The probability generating function Q(λ) for the probability $P_n(\Delta\eta)$ can be defined as [4, 5],

$$Q(\lambda) = \sum_{n=0}^{\infty}(1-\lambda)^n P_n(\Delta\eta) \qquad (1)$$

Where, λ is a real variable and is restricted to a suitable convergence domain. Q(λ) can be written in terms of the reduced factorial cumulant $\bar{K}_N$ as,

$$Q(\lambda) = \exp\left(\sum_{N=1}^{\infty}\frac{(-\lambda\bar{n})^N}{N!}\bar{K}_N\right) \qquad (2)$$

Where, $\bar{n}$ is the average number of particles in the Δη region. Inverting equation (1) we have,

$$P_n(\Delta\eta) = \frac{(-1)^n}{n!}\left(\frac{\partial^n Q(\lambda)}{\partial\lambda^n}\right)_{\lambda=1} \qquad (3)$$

In order to find the probability of producing zero particles in an interval Δη we have to put n = 0 in equation (3). Putting n = 0 in equation (3) we have,

$$P_0(\Delta\eta) = Q(\lambda)|_{\lambda=1} \qquad (4)$$

Equation (4) depicts the relation between $P_0(\Delta\eta)$ and the generating function Q(λ). This probability, $P_0(\Delta\eta)$, in turn may be used as the generating function for P_n,

$$P_n(\Delta\eta) = \frac{(-\bar{n})^n}{n!}\left(\frac{\partial}{\partial\bar{n}}\right)^n P_0(\Delta\eta) \qquad (5)$$

This equation expresses the relation between the *n*-particle and zero-particle probabilities in a region Δη. Besides serving as a generating function, gap probability is also related to the probability $P_n(\Delta\eta)$ with n ≠ 0 through various kinds of moments [1 - 5]. $P_0(\Delta\eta)$ can be written as an expansion in cumulants as,

$$\ln P_0(\Delta\eta) = \sum_{N=1}^{\infty}\frac{(-\bar{n})^N}{N!}\bar{K}_N \qquad (6)$$

Applying the so-called linked pair ansatz to the normalized cumulant moment K_N we obtain,

$$\bar{K}_N = A_N\ \bar{K}_2^{N-1} \qquad (7)$$

If the linking coefficients A_N are independent of the collision energy and pseudo-rapidity interval Δη up to N = 5 [1 -5], then a quantity χ called the scaled rap-gap probability can be constructed such that,

$$\chi = \frac{-\ln P_0(\Delta\eta)}{\bar{n}} \qquad (8)$$

Under the above condition χ depends only on the product of $\bar{n}$ and $\bar{K}_2$. This entitles one to write,

$$\chi = \sum_{N=1}^{\infty} \frac{1}{N!} A_N \left(-\bar{n}K_2\right)^{N-1} = \chi(-\bar{n}K_2) \qquad (9)$$

Since clan production is Poissonian, the average clan multiplicity $\bar{N}$ in an interval $\Delta\eta$ is simply written as,

$$\bar{N} = -\ln P_0(\Delta\eta) \qquad (10)$$

The average number of particles per clan can be given as,

$$\bar{n}_c = \frac{\bar{n}}{\bar{N}} = \frac{1}{\chi} \qquad (11)$$

The relations (10) and (11) will only be valid when the experimentally measured values of χ can be fitted with the NB distribution.

3. Results and discussions

The rap-gap probability $P_0(\Delta\eta)$ is calculated for the first pseudo-rapidity interval ($\Delta\eta$ = 1) centered on zero using $^{84}Kr_{36}$ at ~1 A GeV projectiles colliding with heavy (Ag / Br), light (CNO) groups of targets present in the NED. The value of the pseudo-rapidity interval $\Delta\eta$ is then increased in steps of 1 for each interaction and the value of $P_0(\Delta\eta)$ is computed. To calculate the single-moment combination $\bar{n}K_2$, we have to find the value of $\bar{K}_2$. $\bar{K}_2$ is given by $\bar{K}_2$ = (<F_2> – 1), where <F_2> is the second order factorial moment and given as <F_2> = < n (n – 1) > and n is the number of particles in $\Delta\eta$ region. According to this model, it is assumed that there are two types of source responsible for the multi-particle production one of them is the chaotic source described by the NBD model while the second one is the coherent source described by the minimal model or the hierarchical Poisson model. In terms of the scaled rap-gap probability χ the NBD model can be expressed as χ = ln (1+$\bar{n}K_2$) / $\bar{n}K_2$ and minimal model can be expressed as χ = [1 – exp (– $\bar{n}K_2$) / $\bar{n}K_2$] . The variation of χ with $\bar{n}K_2$ has been shown in figure 1. In figure 1 dotted line and solid line represents fitting of the NBD model and the minimal model respectively. From figure 1, it is seen that for all of the interactions the experimental points lie approximately on the dotted curve not on the solid curve. This study reveals that the scaling behavior of the experimental points is explained by NBD model. Which show that the multiparticle production mechanism is chaotic in nature. From figure 1 it's also cleared that the experimental points for ^{32}S-Ag / Br interactions at 200 AGeV lies in the region bounded by the NBD model fitting curve and the minimal model fitting curve. This observation suggests that the particle production at higher energy is partly chaotic and partly coherent in nature. This signifies that the particle production mechanism is chaotic for low energy interactions while for higher energy interactions it have partly coherent and partly chaotic in nature and our results are also consistence with other experiments.

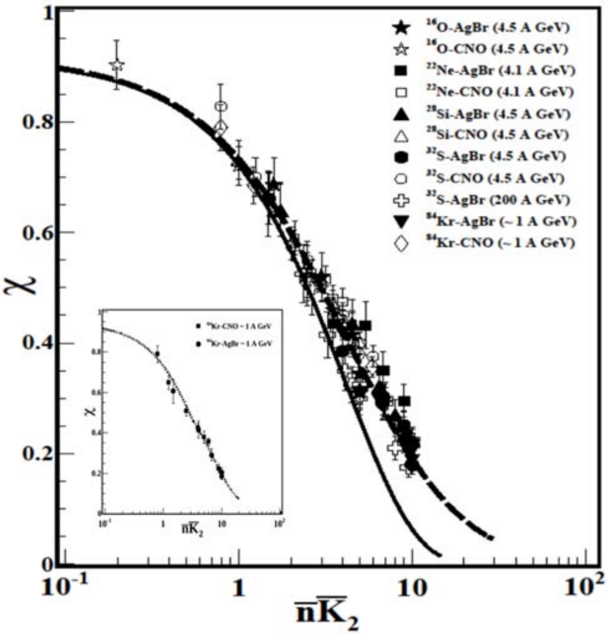

Figure 1: The variation of χ with respect to $\bar{n}K_2$. The experimental data points are from ^{16}O at 4.5 [4, 5], ^{22}Ne at 4.1 [4, 5], ^{28}Si at 4.5 [4, 5], ^{32}S at 4.5 [4, 5], ^{32}S at 200 [4, 5], ^{84}Kr at 0.95 [Present work]. The dotted and solid lines are presenting the fitting of data points with the NBD model and minimal model respectively.

Acknowledgement

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

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