Scaling Nature of Multiplicity Distributions in Relativistic Nuclear Collisions

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Introduction

The scaling of multiplicity distributions of relativistic shower particles and slow particles produced has also been studied in order to check the validity of KNO-scaling. A simplified universal function has been used to represent the experimental data. Finally, some results on the dependence of shower particle multiplicity on the number of interacting projectile nucleons have been made.

The study of multiplicity distributions of hadrons produced in high-energy particle collisions has been made extensively in hadron-hadron, hadron-nucleus and nucleus- nucleus interactions in the past, since such studies are useful in understanding the production processes involved. Koba, Nielsen and Olesen [1] have predicted that the multiplicity distributions of the produced particles in high-energy hadron-hadron collisions should obey a simple scaling law known as KNO scaling when expressed in terms of the scaling variable Z (= n/<n>). If P(n) represents the probability for the production of n charged particles in an inelastic hadron-hadron collisions, the multiplicity distributions in high energy collision obey a scaling law:

$$P(n) = \frac{\sigma(n)}{\sigma_{inel}} = \frac{1}{<n>}\Psi\left(\frac{n}{<n>}\right) \quad (1)$$

$$= \frac{1}{<n>}\Psi(Z) \quad (2)$$

where σ(n) is the partial cross-section for the production of n charged particles, σ_{inel} is the total inelastic cross-section and <n> is the average number of charged particles produced. The KNO scaling thus implies that the multiplicity distribution is universal and $\Psi(Z)$ is an energy independent function at sufficiently high energies when expressed in terms of scaling variable Z.

The other consequences of the KNO scaling are given as:

(i) The normalized moments, $C_k = <N_S{}^k> / <N_S>^k$ of the multiplicity distributions become independent of projectile energy.

(ii) It leads to $D/<N_S>$ = constant; provided $\Psi(Z)$ is not a delta function.

(iii) Central moments, $\sqrt[k]{\mu_k} = \sqrt[k]{(n-<n>)^k}$ of the distribution should have a linear relation with the average multiplicity, <n>, of the reaction.

It has been shown [1,2] that the multiplicity distributions of relativistic shower particles, projectile light fragments and target black fragments obtained from the events of different projectiles over a wide range of energies in nucleus-nucleus collisions can be described by a KNO scaling law. These distributions can be represented by a universal function of the following form:

$$\Psi(Z) = 4Z\exp(-2Z) \quad (3)$$

and

$$\Psi(Z) = AZ\exp(-BZ) \quad (4)$$

where A and B are constants.

A striking regularity has been found to exist in the production of relativistic shower particles in high-energy collisions. In order to study the multiplicity distribution of charged particles produced in ^{28}Si + emulsion collisions at 14.6A GeV, $\Psi(Z)$ as a function of Z is shown in Fig. 1. It is clear from the figure that Eqn. (1) and (2) are found to reproduce the shower particle multiplicity distribution well. One can see that KNO scaling in the form of Eqn. (3) and

(4) seems to qualitatively describe the trend of the multiplicity distribution of secondary particles produced in nucleus- nucleus collisions similar to that found in hadron-hadron and hadron-nucleus collisions. Various workers have also used the same function to describe the multiplicity distributions of nuclear fragments in nucleus-nucleus collisions at Dubna energy. However, the values of the constants A and B may differ for different interactions. The values of χ^2/DOF of the distributions in Fig. 1 are found to be (0.371 ± 0.003) and (0.332 ± 0.002) respectively. If the experimental points from the tail of the curve are not considered due to low significance of experimental data, then χ^2/DOF reduces to (0.305 ± 0.002) and (0.296 ± 0.002) respectively, which of course represents a better fit and confirms the validity of the scaling function. It may be emphasized that by analyzing the data in terms of simplified functions (Eqn. 3 & 4), the value of χ^2 /DOF is also reduced.

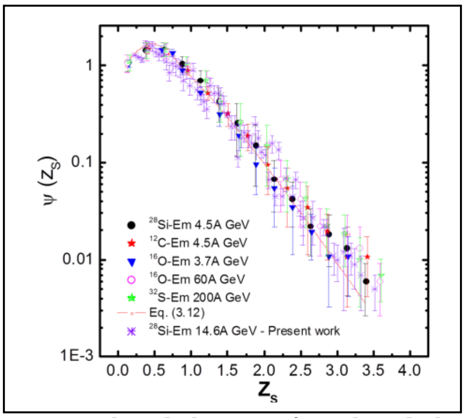

Fig. 1 Scaling behavior of produced charged particles in ^{28}Si+Em collisions at 14.6A GeV.

The following functional form of Ψ_S (Z),

$\Psi_S(Z) = (3.79Z + 33.7Z^3 - 6.64Z^5 + 0.332Z^7)\exp(-3.24Z)$ (5) obtained by Slattery for p-p interactions is also shown in Fig. 1 (a & b)for comparison. It has been observed that the scaling function $\Psi_S(Z)$ fits well the p-p data but when used for nucleus-nucleus data it gives χ^2 / DOF = (3.460 ± 1.212) and (4.924 ± 1.025) respectively which indeed is a poor fit as shown in Fig.1 (a & b).

In order to check the validity of KNO scaling, the normalized moments, C_k, of the multiplicity distributions using Eq. ($C_k = \langle n^k\rangle/\langle n\rangle^k$) are presented in Fig.2. The values of C_2 and C_3 - moments are found to be independent of masses and energy of the projectiles within the experimental errors. On the other hand, the higher moments corresponding to k = 4, 5 show an increasing trend in their values (not shown in the table) as the mass number of the projectile increases. An interesting observation can be seen from the table that the values of $\langle N_S\rangle$/D for different projectiles and targets are approximately equal to that observed in hadron-nucleus interactions [1-2]. This feature indicates that essentially there is a similarity for the production mechanism of two types of collisions.

The linear variation of D (N_S) ($D = [\langle N_S{}^2\rangle - \langle N_S\rangle^2]^{1/2}$) of shower particles as a function of $\langle N_S\rangle$ is shown in Fig. 2 for present work along with the other results [2-3]. The best linear fit is represented by:

$$D = \alpha + \beta \langle N_S\rangle \quad (6)$$

where the values of α and β are found to be (-0.028±0.021) and (0.716± 0.009) respectively.

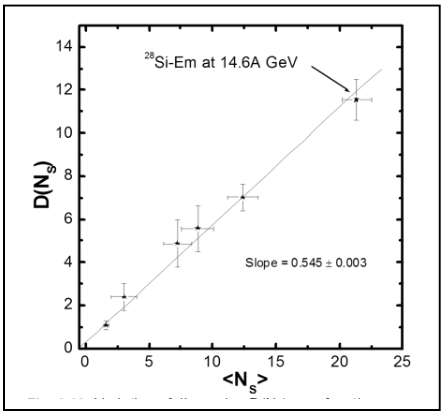

Fig. 2 The dependence of D(N_S) on $\langle N_S\rangle$ of produced charged particles 14.6A GeV.

References

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