A Study of Multiplicity Scaling of Particles Produced in ^{16}O-Nucleus Collisions

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Introduction

Koba-Nielsen-Olesen (KNO) scaling has been a dominant framework to study the behaviour of multiplicity distribution of charged particles produced in high-energy hadronic collisions. Several workers [1-8] have made attempt to investigate multiplicity distributions of particles produced in hadron-hadron (h-h), hadron-nucleus (h-A) and nucleus-nucleus (A-A) collisions at relativistic energies. Multiplicity distributions in p-nucleus interactions in emulsion experiments are found to be consistent with the KNO scaling [6-8]. The applicability of the scaling of multiplicities was extended to FNL energies by earlier workers [3-5]. Slattery [3] has shown that KNO scaling is in agreement with the data on pp interactions over a wide-range of energies. The KNO scaling framework assumes that at a given energy the following relationships:

$$P_n = 1/(<n>) \ \Psi(n/<n>) \quad (1)$$

$$<n> = \sum n P_n \quad (2)$$

are valid, where n and < n > denote respectively the number of secondary charged particles produced in an interaction and their mean for a particular sample and P_n represents the probability of producing n secondaries in the final state of the collision; $\psi(z)$, where $z = n/<n>$ is energy-independent function which satifies the normalization condition: $\int_0^\infty z\psi(z) = 1$.

There are two ways of testing the validity of KNO scaling. In the first approach, there will be an overlap of the data at different projectile energies in $\psi(z)$ versus z plots. In the second, the data at different incident energies should overlap, if sums $S_n(z)$, $S_n(z) = \sum_{i=n}^{\infty} P_i$ are plotted against z. The results reported by the earlier workers [4-8] showed that the data obey approximately the KNO scaling at various beam energies. Nevertheless, the agreement between the data and KNO predictions was not perfect. The shape of the scaling function $\psi(z)$ when plotted against z, has to change with energy in order to obtain the best fit to the data. A sincere effort was made to generalize KNO scaling to KNO-G scaling by Glokhvastov [9]; KNO-G scaling only assumes that there exists a probability distribtion function, $P(\overline{n})$ which is related to P_n in the following way:

$$P_n = \int_n^{n+1} P(\overline{n})\, d\overline{n} \text{ and} \quad (3)$$

$$<\overline{n}> = \sum \overline{n} \ P(\overline{n}) \quad (4)$$

Where $<\overline{n}> = <n> + 0.5$ and scaling function in the modified form is expressed as: $\Psi(\overline{z}) = <\overline{n}> P(\overline{n})$ and $\overline{z} = \overline{n} / <\overline{n}>$. In order to test the validity of KNO-G scaling, behaviour of parameters, $\Psi(\overline{z})$ and $S_n(\overline{z})$ are studied at different projectile energies. In the present work, an attempt is made to investigate the validity of KNO-G scaling in the multiplicity distributions of secondary charged particles produced in 3.7, 60 and 200A GeV/c ^{16}O-nucleus collisions.

Experimental Details

In the present study data on 3.7, 60 and 200A GeV/c ^{16}O-nucleus collisions from SPS, CERN with $n_h \geq 0$, where n_h represents the number of charged particles produced in an interactions with relative velocity, $\beta \leq 0.7$, are analyzed. The number of charged particles having $\beta > 0.7$ in a collision is represented by n_s; the number of compound multiplicity is denoted by n_c such that $n_c = n_s + n_g$, where n_g is the number of charged particles emitted with relative velocity, β, lying in the interval $0.3 \leq \beta \leq 0.7$.

Results and Discussion

Validity of the generalized KNO scaling, KNO-G, for n_s and n_c distributions is tested by studying the behaviours of the variations of $\Psi(\overline{z})$ and $S_n(\overline{z})$ plotts with $\overline{z}$. The KNO-G scaling plots for 3.7, 60 and 200A GeV/c ^{16}O-nucleus collisions are shown in Figs.1 (a,b). It may be noted from the figures that the data at different projectile energies lie approximately closer to the solid curves, obtained by carrying out best fits to the data using:

$$\psi(z) = A \times z e^{-Bz} \quad (5)$$

where A and B are constants. The values of the constants along with their corresponding, χ^2 / D.F. obtained for the best fits to the data using CERN standard program, MINUTE are presented in Table 1. It is clear from the figures that both n_s and n_c distributions are nicely reproduced by the energy-independent function, $\Psi(\bar{z})$. The solid curves in each plot are the best fits to the data obtained by MINUTE programe using Eq. (5). Values of the fit parameters along with the χ^2 / D.F., obtained for the best fits to the data, are listed in Table 1. It may be of interest to note from the Table 1 that parameter A acquires slightly higher value for n_c distribution at 3.7, 60 and 200A GeV/c ^{16}O-nucleus collisions in comparison to those for the n_s distributions. However parameter, B acquire almost same value for the both type of distriburions considered in the present study.

Table 1. **Values of the constants appearing in Eq. (5) for the best fits to the data on** ^{16}O-Em **corresponding to KNO-G scaling function,** $\Psi(\bar{z})$.

Types of distribution	Fit parameters		χ^2 / D.F.
	A	B	
n_s	6.828±0.584	1.832±0.888	0.075
n_c	9.830±0.531	2.182±0.843	0.510

Shown in Figs.2(a,b) are the variations of scaling parameter S_n $(\bar{z})$ with $\bar{z}$ for both n_s and n_c distributions in 3.7, 60 and 200A GeV/c ^{16}O-nucleus collisions. Figs. 2(a,b) show that the experimental results on S_n $(\bar{z})$ corresponding to different projectile energies overlap and scattering is not observed in the case of both of the n_s and n_c distributions. Thus, a graphical test of the KNO-G scaling is displayed in Figs. 1-2. It may be noticed from these plots that all the data points lie on a single curve and scatterings are observed around the tails of the distributions, where largest experimental errors are expected to occur.

Conclusions

Scaling of multiplicities of relativistic charged particles, n_s and compound mutiplicity, n_c , is examined by studying the behaviours of KNO-G scaling function for the data on 3.7, 60 and 200A GeV/c ^{16}O-nucleus collisions. Validity of the KNO-G scaling is tested by studying the behaviours of variations of S_n $(\bar{z})$ versus $\bar{z}$ plots. KNO-G predictions are nearly consistent with the results extracted from the variations of $\Psi(\bar{z})$ and S_n $(\bar{z})$ with $\bar{z}$ for different projectile energies for both n_s and n_c. It may be pointed out that a confirmatory test of the KNO-G validity at LHC energies requires a further analysis of multiplicity data measured in the full phase space.

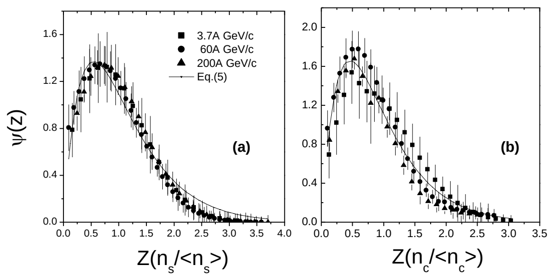

Fig. 1 $\Psi(\bar{z})$ **versus z plots for** n_s **and** n_c **in** ^{16}**O-nucleus collisions.**

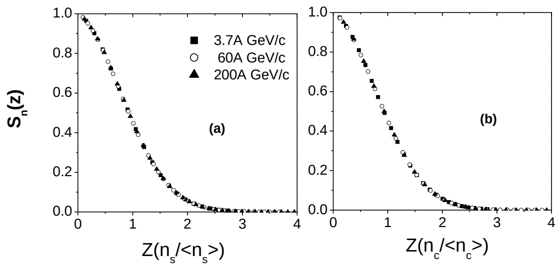

Fig. 2 S_n $(\bar{z})$ **versus** $\bar{z}$ **plots for** n_s **and** n_c **in** ^{16}**O-nucleus collisions**

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