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Systematic study of multiparticle production in nucleus–nucleus interactions at 14.6 A GeV

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Abstract. An experimental analysis of 855 events induced by 14.6 A GeV ^{28}Si in nuclear emulsion is presented. Mean multiplicities of charged secondary particles produced in the nuclear interactions are studied and compared with the results from the other experiments for the same projectile at 3.7 A GeV as well as data for proton at similar energy (14 GeV). An analysis of pseudorapidity densities of target fragments (black and grey particles) is also performed. The behaviour of the KNO scaling law of the multiplicity distribution for shower particles has been examined. In order to accumulate knowledge about the intermittent behaviour of shower particles, the scaled factorial moments (SFMs) are computed in η-space and ϕ-space for a set of data in the ^{28}Si–AgBr events. Furthermore, validity of limiting fragmentation of shower particles produced in central collision events induced by ^{28}Si-emulsion interactions has been tested. A crude estimation for the energy density of the nuclear matter formed in the central collision events at our energy has been examined.

Keywords. Nuclear emulsion; Pseudorapidity; scaled factorial moments; limiting fragmentation; energy density.

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1. Introduction

In heavy-ion collisions at relativistic high energy, a large amount of energy is deposited by the nucleons of colliding nuclei in a very small region of space so that the energy density becomes very high (the order of few GeV/fm^3) for a very short period of time. The space–time evolution of such collision processes undergo various substages resulting at last in the production of final-state particles [1–5]. These final-state particles carry several informations of great significance related to the particle production mechanism involved in a nucleus–nucleus collision. Therefore, the investigation of these charged secondary particles plays a role of utmost importance in analysing such types of collision processes. In order to achieve this objective, it is obviously necessary to obtain a considerable amount of experimental information on diverse characteristics of such collisions such as the multiparticle production in heavy-ion collisions at relativistic energy. Therefore, our detailed study on multiparticle production mechanism involves the analysis of various features of collision physics such as (1) the general characteristics of the produced charged secondary particles such as mean multiplicities, (2) non-statistical fluctuations in the multiplicity of final-state particles, (3) well-known scaling laws existing in high-energy collisions such as KNO scaling and longitudinal scaling (limiting fragmentation), and (4) estimation of energy density of nuclear matter formed under extreme conditions. In this study, the analysis of the non-statistical fluctuations of the charged secondary particles plays a vital role in developing a better understanding about the multiparticle production mechanism of the nucleus–nucleus interactions at relativistic high energies. To decouple these non-statistical fluctuations intermingled with the statistical noise in the multiplicity data, Bialas and Pechansky [6] first introduced a method known as 'intermittency' to study the dependence of the normalized factorial moments on the bin size δy in rapidity space [7]. These scaled factorial moments (SFMs) are benefited with the property to suppress the statistical noise present in a collision event with finite multiplicity and they are capable of eliminating it completely in the case of Poissonian noise. Moreover, the method of SFMs provide us a potentially suitable probe in the investigation of the multiplicity correlations and/or for high-order correlations which would otherwise be inaccessible [8]. This intermittent behaviour has been observed in various experiments performed with a wide variety of colliding systems at different energies such as electron–positron [9–12], hadron–hadron [13–17], hadron–nucleus [18–20], and nucleus–nucleus interactions [21–32]. The search for certain systematics or scaling relations which are universal to all types of reactions, i.e., lepton–hadron, hadron–hadron, hadron–nucleus, and nucleus–nucleus interactions, are of great relevance for studying the collision dynamics involved in these interactions. Among these scaling phenomena, longitudinal scaling (limiting fragmentation) which was first proposed by Benecke *et al* [33] is of the great importance in the study of these nuclear collisions. Moreover, longitudinal scaling of the produced particles has been a defining property of high-energy collisions. These systematics or scaling laws reveal the underlying production mechanism of the multiparticle production. Any violation of these scaling laws observed in ultrarelativistic nuclear collisions will be an indicator of a new and exotic phenomenon occurring there. In the present work, we present and discuss experimental data on the main characteristics such as mean multiplicity of fast (such as singly charged produced shower particles) and slow particles (emanating from the target nuclei of emulsion detector known as black and grey particles) of inelastic collisions of ^{28}Si nuclei with nuclear emulsion at 14.6 A GeV energy. A comparison of our present ^{28}Si data at 14.6 A GeV is made with the ^{16}O data available at the same energy [34] as well as proton data at 14 GeV [35]. The variation of SFMs with the bin size in pseudorapidity (η)-space and in the azimuthal angle (ϕ)-space is investigated separately in order to analyse the dynamical fluctuations in nucleus–nucleus interactions at 14.6 A GeV. We have also shown the energy-independent behaviour of the limiting fragmentation phenomenon for the central collision events and also compared these observations with the predictions of Lund Monte Carlo model FRITIOF. In the last section, we also calculate the energy density of the nuclear matter formed in central collision event with highest multiplicity at our energy.

2. Experimental details

The present data are collected using a stack of Fuji emulsion pellicles exposed horizontally with a ^{28}Si beam at 14.6 A GeV at BNL AGS, New York. An along-the-track scanning technique was used to locate the minimum-bias ^{28}Si emulsion interaction events. An OLYMPUS BH2 microscope with a 100× oil immersion objective under a total magnification of 2250 was used for the scanning purpose. The primary beam track in the emulsion pellicles was carefully followed up to a distance of 4 cm from the entrance edge. Events produced very close to the top or bottom surface of the emulsion up to 20 μm were not taken into account for the investigation. A total of 855 inelastic events have been taken into account for our investigation. Charged secondary particles emitted in each interaction were divided according to their ionization, range and velocity into black (b), grey (g), shower (s) and projectile fragments (PF_s) having charges $Z \geq 2$. Black particles are slow velocity particles with $\beta < 0.3$ having range less than 3 mm in emulsion and ionization $g > 6g_{\min}$, where $g_{\min}$ is the grain density of singly-charged particle moving with velocity close to initial beam velocity. These are low-energy, multiply charged fragments and are mainly evaporated particles from the target nuclei. Grey particles have a range greater than 3 mm and ionization $1.4g_{\min} < g \leq 6g_{\min}$. These particles are mainly knocked out protons from the target nucleus. Both the black and grey particles are target fragments. Shower particles are fast particles having ionization $g \leq 1.4g_{\min}$ and velocity $\beta > 0.7$. These particles are mainly relativistic pions, with a small fraction of K-mesons and fast protons. Projectile fragments (PF_s) with $Z \geq 2$ have $g \geq 4g_{\min}$, emitted in a narrow forward cone. The multiplicities of black, grey, shower and projectile fragments are denoted by n_b, n_g, n_s and n_F respectively. Black and grey particles collectively are called heavily (h) ionizing particles such that $n_h = n_b + n_g$. Black, grey and shower particles collectively are called the total charged (ch) particles such that $n_{ch} = n_b + n_g + n_s$. Nuclear emulsion is composed of different targets H, C, N, O, Ag, Br and I nuclei. A clear identification of these different targets in nuclear emulsion is not so straightforward. Statistically, identification of collision events with different target nuclei in nuclear emulsion is performed on the basis of the multiplicity of heavy particles (n_h). On this basis, different collision events in nuclear emulsion are characterized as H events, CNO events and AgBr events. A detailed desciption of the target identification can be found in ref. [36]. The rapidity variable is defined as

$$y = \frac{1}{2}\ln\frac{E - p_l}{E - p_l},$$

where E and p_l are the energy and longitudinal momentum of the detected particle. The measurements of energy and momentum are difficult in experiments like emulsion experiments. The pseudorapidity variable (η) approximately coincides with the dimensionless boost parameter rapidity (y) at very high energy and can be easily determined using only one quantity, i.e., emission angle (θ) of the corresponding shower particle. It is defined as

$$\eta = -\ln \tan \frac{\theta}{2}.$$

Thus, the pseudorapidity variable is a convenient and suitable replacement of the rapidity variable.

3. Mean multiplicities and pseudorapidity distribution

In table 1, we have shown the mean multiplicities of different charged secondary particles at 14.6 A GeV for ^{28}Si emulsion interactions and for ^{16}O emulsion interactions [34] along with the data at similar energy (14 GeV) for p-emulsion interaction [35]. It is observed that mean multiplicity of shower particles at 14.6 A GeV for ^{28}Si emulsion interactions is higher than the mean multiplicity of shower particles for ^{16}O emulsion interactions [34] at the same energy. This increase in the mean multiplicity of shower particles at the same energy is due to the increased size of the projectile nuclei. The mean multiplicity of black, grey, heavily ionizing particles and shower particles for ^{28}Si emulsion interactions at 3.7 A GeV [37] are 4.32 ± 0.14, 6.50 ± 0.32, 10.82 ± 0.35 and 15.32 ± 0.51 respectively.

Mean multiplicity of shower particles at 14.6 A GeV for ^{28}Si emulsion interactions is much higher than the mean multiplicity of shower particles for ^{28}Si emulsion interactions at 3.7 A GeV [37] because of the increased energy of ^{28}Si projectile beam, as most of the energy goes into the production of shower particles. However, within the experimental error, we can see that mean multiplicity of target fragments (n_{h}) shows almost no dependence on the incident projectile beam energy. This result resembles the well-known limiting behaviour of the target fragmentation process in high-energy hadron–nucleus [38] and nucleus–nucleus interactions [39].

Stopping power in nucleus–nucleus interactions at high energies is a topic of particular interest because high stopping can give a high baryon density providing a basis for phase transitions. Furthermore, the slowing down of baryons gives rise to large emission of newly produced particles such as pions and other hadrons, contributing to abundant particle production in these nuclear collisions. Thus, the degree of nuclear stopping in heavy-ion collisions is an observable necessary to understand the basic reaction dynamics. For this study, in figure 1, we have shown the pseudorapidity distribution of black

Table 1. Mean multiplicities of black (b), grey (g), heavily ionizing (h) and shower (s) particles in ^{28}Si emulsion interactions at 14.6 A GeV, ^{16}O emulsion interactions at 14.6 A GeV [34] and p-emulsion interactions at 14 GeV [35].

Interactions	Energy	$\langle n_{\mathrm{b}} \rangle$	$\langle n_{\mathrm{g}} \rangle$	$\langle n_{\mathrm{h}} \rangle$	$\langle n_{\mathrm{s}} \rangle$	Reference
p-emulsion	14 GeV	–	–	8.4±0.37	4.9±0.10	[35]
^{28}Si emulsion	14.6 A GeV	6.33±0.22	2.52±0.08	8.85±0.30	30.41±1.04	Present work
^{16}O emulsion	14.6 A GeV	4.80±0.20	5.20±0.20	–	20.30±0.80	[34]

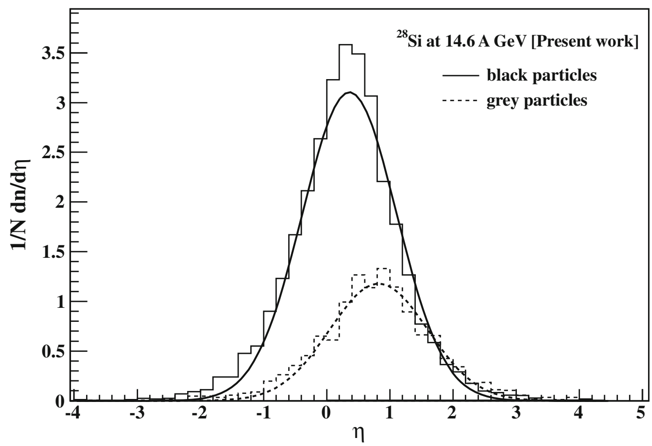

Figure 1. Pseudorapidity distributions of black and grey particles in nucleus–nucleus interactions at 14.6 A GeV.

and grey particles (i.e. target protons) emanating in nucleus–nucleus interactions at 14.6 A GeV. The pseudorapidity distribution of black particles (shown in figure 1 by solid-line histogram) has a peak around $\eta \approx 0.2$ and it lies within the range $-4.0 \leq \eta \leq 4.4$. Similarly, the pseudorapidity distribution of grey particles (shown in figure 1 by dashed-line histogram) has a peak around $\eta \approx 0.8$ and it lies within a range $-4.0 \leq \eta \leq 4.2$. Both the distributions are well fitted with Gaussian function of $\rho_0 \exp((\eta^2 - \mu^2)/2\sigma^2)$. The values of ρ_0, μ and σ of fitted Gaussian function for black particles are 3.10 ± 0.12, 0.35 ± 0.03 and 0.75 ± 0.03. Similarly, the values of these parameters of fitted Gaussian function for grey particles are 1.18 ± 0.03, 0.82 ± 0.03 and 0.78 ± 0.03. In case of full transparency, one would expect the final target protons to exhibit a peak at target rapidity. On the other hand, if the nuclei are fully stopped, one would expect most of the target nucleons to be around midrapidity. Target and projectile beam rapidity in nucleus–nucleus interactions at 14.6 A GeV are 0 and 3.5 respectively [40]. From figure 1, we observe a shift of the peaks in both cases (i.e., black and grey particle) towards midrapidity away from target rapidity with some width of the distributions. This clearly indicates a large degree of stopping, i.e., a large baryon density achieved in nucleus–nucleus interactions at 14.6 A GeV. Furthermore, we can also observe that the black particles (which are mainly evaporated protons from the target nuclei) are produced in more abundance than the grey particles (which are knocked out protons from the target nucleus) almost over the entire range of pseudorapidity.

4. Intermittent behaviour

In this section, we discuss 1d intermittency analysis of the shower particles produced in ^{28}Si–Ag/Br (i.e. events with $n_h \geq 8$) interactions at 14.6 A GeV in pseudorapidity (η)-space and in azimuthal angle (ϕ)-space. The dependence of normalized factorial is studied in azimuthal plane (transverse) for a better visibility of the significance of the slopes. In an experiment, the statistical noise along with dynamical fluctuations are observed collectively to the particle density. The scaled factorial moments (SFMs) reduce the statistical noise which is present in event with finite multiplicity. Moreover, the method of SFMs is potentially suitable for investigating the multiparticle correlation on small scales. In this analysis, the pseudorapidity interval of the total length $\Delta\eta = \eta_{\max} - \eta_{\min}$, is partitioned into M bins of equal size such that $\delta\eta = \Delta\eta/M$.

The single-event factorial moment of order q is defined as

$$F_q^e = \frac{1}{M}\sum_{m=1}^{M}\frac{n_m(n_m-1)\cdots(n_m-q+1)}{(1/M\sum_{m=1}^{M} n_m)^q}, \tag{1}$$

where M is the pseudorapidity interval number and n_{m} is the number of particles falling within the mth interval in an event. By averaging F_q^e over N events present in a particular sample, one gets the so-called horizontally averaged scaled factorial moment

$$\langle F_q^e\rangle = \frac{1}{N_{\mathrm{ev}}}\sum_{e=1}^{N} F_q^e. \tag{2}$$

The horizontally averaged moment as defined above is sensitive to the shape of the single-particle density distribution and depends on the correlation between the cells. The problem associated with the shape dependence of the single-particle density distribution can be taken care of either by introducing the Fialkowski correction factor [41] or by converting the phase-space variable to a cumulative variable [42],

$$\chi(\eta) = \frac{\int_{\eta_{\min}}^{\eta}\rho(\eta')\mathrm{d}\eta'}{\int_{\eta_{\min}}^{\eta_{\max}}\rho(\eta')\mathrm{d}\eta'} \tag{3}$$

the single-particle density distribution in terms of $\chi(\eta)$ is always uniform between 0 and 1. The power-law scaling behaviour of the factorial moments,

$$\langle F_q\rangle \propto M^{\phi_q}, \tag{4}$$

where ϕ_q is called the intermittency index. This power-law behaviour gives the following linear relation of the form:

$$\ln\langle F_q\rangle = \phi_q \ln M + \beta_q. \tag{5}$$

We have shown $\ln\langle F_q\rangle$ against $\ln M$ for the order q =2,...,6 in η-space and ϕ-space in figures 2 and 3, respectively. In figure 2, we can clearly observe that $\ln\langle F(\eta)_q\rangle$ shows a linear dependence on $\ln M$ in η-space which clearly indicates a power-law behaviour of the F_q moments on $\delta\eta$. For each order q, a linear fit using least square fitting method is performed. The values of the slopes ϕ_q of the least square straight line fitting of the data points for each order of q are found to be 0.011±0.02, 0.04±0.02, 0.11±0.04,0.25±0.07, 0.47±0.10 respectively.

Similarly, in figure 3, we can clearly observe that $\ln\langle F(\phi)_q\rangle$ shows a linear dependence on $\ln M$ in ϕ-space which clearly indicates a power-law behaviour of the F_q moments on $\delta\phi$. For each order q, a linear fit using least square fitting method is performed. The values of the slopes ϕ_q of the least square straight line fitting of the data points for each order of q are found to be 0.004±0.017, 0.019±0.009, 0.07±0.037, 0.22±0.06, 0.50±0.09

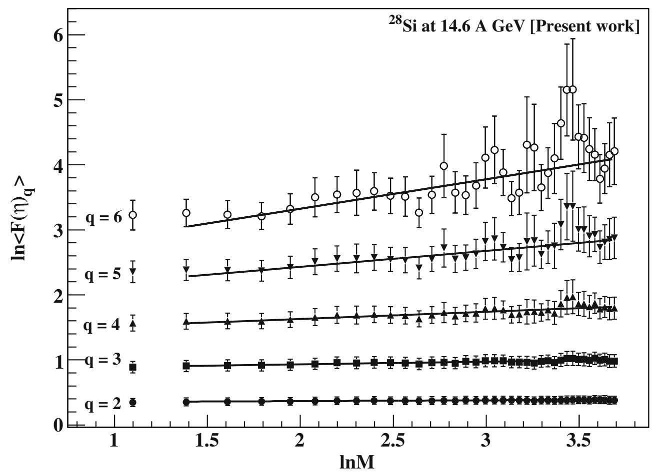

Figure 2. Intermittency of shower particles produced in η-space in ^{28}Si–Ag/Br interactions at 14.6 A GeV.

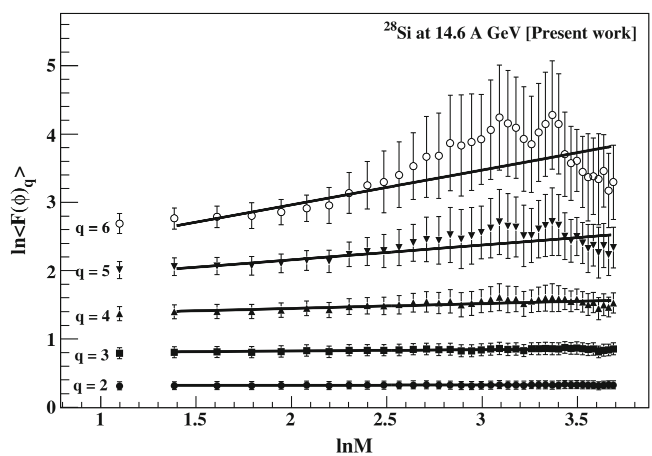

Figure 3. Intermittency of shower particles produced in ϕ-space in ^{28}Si–Ag/Br interactions at 14.6 A GeV.

respectively. This power-law dependence of F_q moments on $\delta\eta$ and $\delta\phi$ suggests that the data points are highly correlated. One can easily observe the linear rise of the factorial moments in both η- and ϕ-space but the slope values (ϕ_q) are consistently larger in the ϕ-space than in the η-space. Higher values of ϕ_q in ϕ-space may be due to the fact that to conserve transverse momentum, the particles probably experience extra correlation in azimuthal plane [43]. Moreover, this power-law dependence of SFMs in both η- and ϕ-space reflects the underlying scale invariant dynamics in the multiparticle production in nucleus–nucleus interactions at 14.6 A GeV.

5. KNO Scaling

An impressive regularity has been found to exist for several years in the multiplicity distribution of the produced particles. The probability distribution for the production of n relativistic charged particles in hadron–hadron interactions exhibits a universal behaviour. Koba *et al* [44] predicted that at asymptotic energies, the probability $P(n)$ of the production of n charged particles in hadron–hadron interactions in the final states is associated with a scaling function $\Psi(z)$ in the form:

$$P(n) = \frac{1}{\langle n\rangle}\Psi(z) = \frac{\sigma_n}{\sigma_{\text{inel}}}, \tag{6}$$

where $\Psi(z)$ is universal and independent of energy. The variable $z = n/\langle n\rangle$ stands for normalized multiplicity, $\langle n\rangle$ represents the average number of charged secondary particles, σ_n is a partial cross-section for producing n charged particles and σ_{inel} is the total inelastic cross-section. This asymptotic prediction of Koba *et al* regarding the scaling behaviour of charged particle multiplicity distribution was examined by Slattery [45] for a wide range of 50–300 GeV/c incident momentum for multiplicity in proton–proton interactions. In order to provide an extension of KNO scaling law at lower energies, a simple empirical modification was put forward by Buras *et al* [46]. The modified KNO scaling law has the following form:

$$P(n) = \frac{1}{\langle n\rangle - \alpha}\Psi(z'), \tag{7}$$

where $z' = (n-\alpha)/(\langle n\rangle - \alpha)$. Here α takes care of leading particle effect and is a constant independent of energy. It only depends on the reaction.

Figure 4 shows the dependence of $\Psi(z')$ as a function of z'. Our experimental data points lie on the universal curve, which can be fitted with a KNO-type scaling function of the following form:

$$\Psi(z') = (6.31z' + 0.90z'^3 - 0.01z'^5 + 0.33z'^7)\exp(-3.19z'). \tag{8}$$

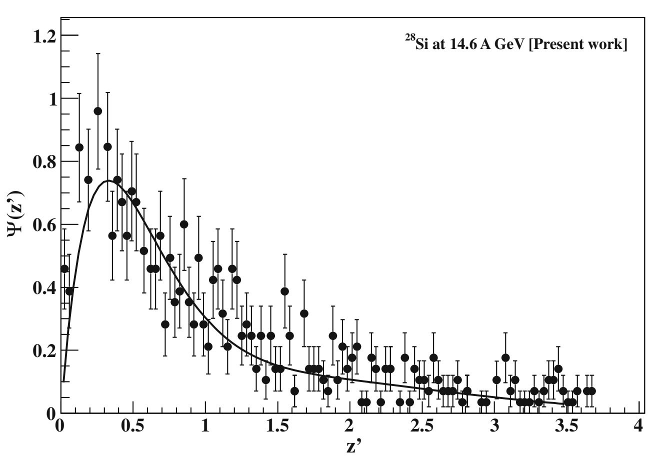

Figure 4. Dependence of $\Psi(z')$ as a function of z'.

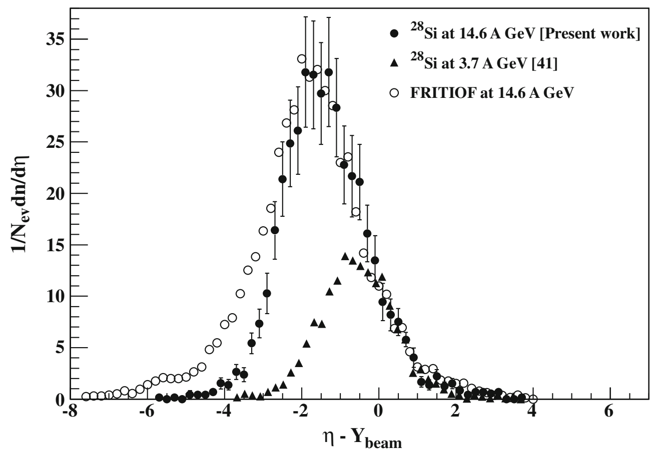

Figure 5. The pseudorapidity distribution of shower particles in central events in nucleus–nucleus interactions at 14.6 A GeV along with comparison with FRITIOF model at the same energy and with the published data at 3.7 A GeV [47] in projectile rest frame.

The value of χ^2 per degree of freedom is 1.04. Thus, we can see that our experimental data are having a consistency with the KNO scaling hypothesis. We can also describe the KNO scaling law in terms of the multiplicity moments which can be defined as follows:

$$C_q = \frac{\langle (n-\alpha)^q \rangle}{\langle n-\alpha \rangle^q}. \tag{9}$$

Using the above expression for multiplicity moments, we have calculated $C_2 = 1.69 \pm 0.06$, $C_3 = 3.72 \pm 0.13$ and dispersion $D = 28.77 \pm 0.98$ for ^{28}Si emulsion interactions at 14.6 A GeV energy, while, for ^{28}Si emulsion interactions at 3.7 A GeV [37] energy, the values of multiplicity moments are $C_2 = 1.46 \pm 0.11$, $C_3 = 2.81 \pm 0.20$ and dispersion $D = 10.08 \pm 0.22$.

6. Limiting fragmentation

In figure 5, we have depicted the normalized pseudorapidity distribution of shower particles produced in central collision events ($n_h \geq 28$) in ^{28}Si emulsion interactions at 14.6 A GeV in projectile rest frame and compared with the published data for central collision at 3.7 A GeV [47]. We also compare our data with the data at 14.6 A GeV generated by FRITIOF code [48], i.e., the Lund Monte Carlo simulation code for the inelastic hadron–hadron, hadron–nucleus and nucleus–nucleus interactions. Pseudorapidity distribution of shower particles in projectile rest frame is obtained using the beam rapidity value Y_{beam} mentioned in ref. [40]. From figure 5, we clearly see the evidence for limiting fragmentation in the projectile fragmentation region for central collision events, where the two distributions at 14.6 A GeV and 3.7 A GeV lie over the top of each other for $\eta - Y_{beam} \geq 0.0$. We also observe that FRITIOF model simulation corroborates the present data at 14.6 A

GeV for central collision events, although the shape of the distribution in target fragmentation region is little broader than the distribution of the experimental data, it fulfills the criteria of limiting fragmentation in projectile fragmentation region.

7. Estimation of energy density

In central collision events, multiparticle production of a large number of secondary hadrons confined to a definite volume provides a quite large density of energy released during a short period of time and thus hints at the possibility of some new/exotic phenomenon such as the formation of quark–gluon plasma. The large energy density of this kind will appear in the form of a large multiplicity density in rapidity space ($\mathrm{d}n_\mathrm{s}/\mathrm{d}\eta$) in central collision events. Therefore, estimation of energy density in the analysis of high multiplicity events will be exceedingly useful in revealing the properties of hadronic matter under extreme conditions. Many authors [47,49,50] in the past reported the estimated value of energy density using the pseudorapidity density value observed in highest shower multiplicity events produced in central collision events at respective energies. They calculated the value of energy density based on the application of Bjorken's formula [1]

$$\varepsilon = \frac{3}{2}\sqrt{\langle p_\mathrm{T}\rangle^2 + m_\pi^2}(\mathrm{d}n_\mathrm{s}/\mathrm{d}\eta)/\tau_0 \pi r_0^2 A^{2/3}, \tag{10}$$

where τ_0 is the hadronic formation time (1 fm/c) and A is the mass number of the smaller nucleus in the collision. Out of central collision events, the highest multiplicity event with $n_\mathrm{s} = 146$ and $n_\mathrm{h} = 26$ corresponds to central collision event with AgBr. The pseudorapidity distribution of shower particles in this high multiplicity single event is presented in figure 6. For the peak value of pseudorapidity density shown in figure 6, we obtain an approximate value of energy density $\varepsilon = 0.97$ GeV/fm^3. This crude estimated

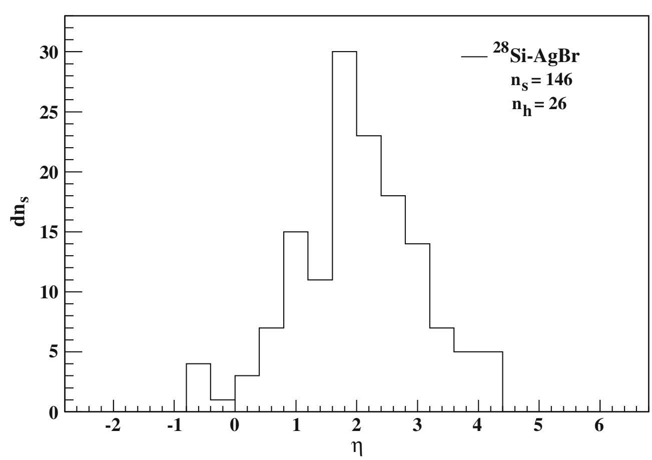

Figure 6. The pseudorapidity distribution of shower particles in single central events with highest multiplicity in nucleus–nucleus interactions at 14.6 A GeV.

value for the energy density is about 6 times higher than the ground state energy of the nuclear matter and is quite closer to the value of 1 GeV/fm^3 nominally predicted for QGP formation [8,51]. This estimated value of energy density is a crude approximation because the value of hadronic formation time (τ_0) still needs some more justification [52]. This result is crude also in the sense that Bjorken's formula is valid for non-stopping regime. A better interpretation of the data can be made using the method of Landau hydrodynamics [53] or the method of Goldhaber [54] for calculating the energy density in stopping regime. In the case of central collision of two equal nuclei, the energy density of the system in Landau hydrodynamics can be given by

$$\varepsilon = E/V = \gamma\sqrt{s_{\mathrm{NN}}}/(4\pi r_0^3/3), \tag{11}$$

where $r_0 = 1.2$ fm, $\sqrt{s_{\mathrm{NN}}}$ is the c.m. energy and γ is the Lorentz contraction factor given by $\gamma = \sqrt{s_{\mathrm{NN}}}/2m_p$. The calculated value of energy density comes out to be $\varepsilon \approx 2$ GeV/fm^3. Similarly, in Goldhaber method, consider the nucleus–nucleus (A–A) collision in the centre-of-mass system and assume that the nuclei in a central collision are able to stop each other. If $\gamma_{\mathrm{c.m.}}$ is the Lorentz transformation factor, then the energy density is given by

$$\varepsilon = 2\gamma_{\mathrm{c.m.}}^2\varepsilon_0, \tag{12}$$

where ε_0 is the energy density of the normal nuclear matter (≈ 0.14 GeV/fm^3). For ^{28}Si–AgBr collision at 14.6 A GeV, we get $\varepsilon \approx 1$ GeV/fm^3.

8. Summary and conclusions

From the extensive analysis of ^{28}Si emulsion interactions at 14.6 A GeV, we conclude that:

(1) A large increase in the mean multiplicity of shower particles is observed at 14.6 A GeV energy in comparison to the the mean multiplicity at 3.7 A GeV, which is due to the increased incident energy of projectile beam.
(2) A comparatively large production of black particles is observed in comparison to the grey particles produced in nucleus–nucleus interactions at 14.6 A GeV.
(3) Intermittent behaviour of shower particle multiplicity is clearly observed in nucleus–nucleus interactions at 14.6 A GeV energy. Intermittency in the ϕ-space is found to be little more stronger than in the η-space.
(4) The multiplicity distribution for shower particles give a reasonable agreement with a modified KNO-type scaling law with a good χ^2 per degree of freedom 1.04.
(5) The energy-independent behaviour of the limiting fragmentation phenomenon for shower particles in central collision events is clearly observed in the projectile fragmentation region and is in quite good agreement with FRITIOF model.

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