CHAPTER V

Pseudorapidity and rapidity-gap distributions
5.1 Introduction

Study of the angular characteristics of charged shower particles produced in nucleus-nucleus interactions is expected to yield some useful information about the production mechanism of the secondary particles. It may be mentioned that the angular characteristics of relativistic charged particles produced in hadron-hadron and hadron-nucleus interactions have been extensively investigated[1-6], whereas much work has not been done to study the problem in the case of nucleus-nucleus collisions.

Angular characteristics of charged shower particles produced in nucleus-nucleus collisions at relativistic energies are investigated in terms of the rapidity variable, \( Y \), defined as

\[
Y = \frac{1}{2} \ln \frac{E + p_L}{E - p_L} \tag{5.1}
\]

where \( E \) and \( p_L \) are the energy and longitudinal momentum of the shower particles respectively. Since majority of the shower particles are pions with a mean transverse momentum \( \sim 0.4 \text{ GeV/c} \) with \( p_T^2 \gg p_L^2 \gg m^2 \), where \( p_T \) and \( m \) denote respectively the transverse momentum and mass of the pion, therefore, Eq.(5.1) would become:

\[
\eta \approx Y \approx -\ln \tan \frac{\theta}{2} \tag{5.2}
\]

where \( \theta \) is the emission angle of a charged shower particle with respect to the mean direction of the primary in the laboratory frame and \( \eta \) is referred to as its pseudorapidity.
This chapter deals mainly with the study of $\eta$-distributions and its related parameters such as dispersion, shower width distribution, etc. Results based on the studies of the rapidity-gap correlations and the production mechanism of heavy clusters have also been presented in this chapter.

5.2 Experimental results

Random samples involving 852 and 1024 events produced in carbon- and silicon-emulsion interactions respectively at 4.5 GeV per nucleon have been analyzed to study the above stated problems in detail. Following criterion has been adopted to select the shower tracks for the analysis. Shower particles having space angles less than $\theta_0$ in the laboratory frame; where the values of $\theta_0$ are $2.00^\circ$ and $3.42^\circ$ for carbon- and silicon-emulsion interactions respectively, are not included. This has been done to exclude the contribution of the projectile fragments.

5.2.1 Dependence of pseudorapidity distribution on the projectile mass

In order to examine the dependence of $\eta$-distribution on the projectile mass, the $\eta$-distributions for the two projectiles— carbon and silicon nuclei— both at 4.5 GeV per nucleon are plotted in Fig. 5.1. It is seen from the figure that the shapes of the $\eta$-spectra are practically similar for carbon- and silicon-emulsion interactions. However, the excess of the particles arising due to an increase in the projectile mass tends to appear only in the central region of
Fig. 5.1 Pseudorapidity distributions of shower particles produced in 4.5 A GeV carbon- and silicon-nucleus interactions.
the rapidity space. Hence, it may be stated that the $\eta$-distributions in the target fragmentation region are almost independent of the projectile mass. Similar results have also been obtained[1-3] in the case of high energy hadron-nucleus collisions.

5.2.2 Dependence of $\eta$-spectrum on $N_g$

Dependence of the $\eta$-distribution of charged shower particles with star size is investigated by dividing the entire data in different $N_g$-bins, i.e., $N_g = 0$, 1, 2-3, 4-5, 6-8 and $\geq 9$. The $\eta$-distributions for different $N_g$-bins at 4.5 GeV per nucleon projectile energy for carbon and silicon nuclei are displayed in Figs. 5.2 and 5.3. It is clear from the figures that the maxima of the $\eta$-spectra shift towards lower values of $\eta$ with increasing target thickness. It may be of interest to mention that the behaviour of the $\eta$-distributions for different effective target thicknesses are similar to those observed for hadron-nucleus collisions[4-6]. This result supports fairly well the predictions of the coherent tube model[7].

5.2.3 Dependence of $<\eta>$ on $N_g$, $N_s$ and $N_h$

Variations of the average value of pseudorapidity of charged shower particles, $<\eta>$, produced in carbon- and silicon-emulsion interactions with $N_g$, $N_s$ and $N_h$ are shown in Figs.5.4(a) and 5.5(a). It is interesting to note from the figures that $<\eta>$ decreases monotonically with increasing $N_g$, $N_s$ and $N_h$. $<\eta>$ versus $\ln N_g$ and $\ln N_h$ plots are exhibited in
Fig. 5.2 $\eta$-distributions for different $N_g$-intervals of carbon-nucleus interactions.
Fig. 5.3 $\eta$-spectra for different $N_g$-bins of $^{28}$Si-Em interactions.
Fig. 5.4(a) Dependence of $\langle \eta \rangle$ on $N_s$, $N_g$ and $N_h$ in $^{12}$C-Em interactions.
Fig. 5.4(b) Dependence of $<l>$ on $\ln N_g$ and $\ln N_h$ in $^{12}\text{C-Em}$ interactions. The solid lines are hand drawn fits to the data.
Fig. 5.5(a) Variation of $\langle \eta \rangle$ with $N_s, N_g$ and $N_h$ in $^{28}\text{Si-Em}$ interaction.
Fig. 5.5(b) Dependence of $\langle \gamma \rangle$ on $\ln N_g$ and $\ln N_h$ in $^{28}$Si-Em interactions. The solid lines are hand drawn fits to the data.
Figs. 5.4(b) and 5.5(b) and a linear relationships between $\langle \eta \rangle$ and $\ln N_g$, $\ln N_h$ are observed. It may be noted that in the case of high energy hadron-nucleus interactions, similar results have been observed [4-6]. This observation is incidentally inconsistent with the predictions of the tube type models.

5.3  Analysis of dispersion of rapidity

It has been suggested by Berger et al [8] that the rapidity dispersion parameter for the individual events can be used to measure the clustering of the produced particles along the longitudinal rapidity axis at high energies. Following this suggestion, dispersion for each event is calculated using the relation:

$$D(\eta) = \left[ \frac{1}{N_s-1} \sum_{i=1}^{N_s} \left( \eta_i - \langle \eta \rangle \right)^2 \right]^{1/2}$$  \hspace{1cm} (5.3)

where $\langle \eta \rangle = \frac{1}{N_s} \sum_{i=1}^{N_s} \eta_i$

Berger et al [8] have also suggested that the events having $D(\eta) < 0.9$ correspond to the production of a single isotopic cluster.

5.3.1  Distribution of rapidity dispersion

Fig. 5.6 shows the frequency distribution of rapidity dispersion for carbon- and silicon-emulsion collisions at 4.5 GeV per nucleon. It may be seen from the figure that the peak of the distribution shifts towards lower values of dispersion with increasing projectile mass. The percentages of the events having $D(\eta) < 0.9$ are 70.69±2.19 and 68.80±2.00
Fig. 5.6 Frequency distribution of dispersion for $^{12}\text{C}$- and $^{28}\text{Si}$-emulsion interactions.
respectively for carbon- and silicon-emulsion interactions. Thus, the probability of the events slightly decreases with the increase in the projectile mass. On the basis of the above observation, it may be stated that clusterization occurs significantly in both carbon- and silicon-emulsion reactions.

5.3.2 Variation of $<D(\eta)>$ with $N_s$

Variation of the average dispersion of $\eta$-distribution $<D(\eta)>$ of the charged shower particles with $N_s$ are plotted in Figs. 5.7(a) and 5.8(a) for carbon- and silicon-emulsion collisions. It may be seen from these figures that $<D(\eta)>$ does not exhibit any appreciable change with increasing $N_s$, except in the region of small values of $N_s$, where a large part of the cross-section is envisaged to be governed by the peripheral collisions with probably one intranuclear nucleon. It is also observed that nearly all the data points lie below the line satisfying the condition $<D(\eta)> \leq 0.9$.

An attempt is made to examine the behaviour of the dispersion of the rapidity dispersion $\omega$. If $D(\eta)$ is a measure of the clusterization, $\omega$ is a measure of the fluctuations in the cluster widths in the rapidity space. The dispersion of the rapidity dispersion is defined as

$$\omega = \left[ \frac{1}{N-1} \sum_{i=1}^{N} \left( <D> - D_i \right)^2 \right]^{1/2}$$  \hspace{1cm} (5.4)$$

where $N$ represents the number of events. It may be noted that Figs. 5.7(b) and 5.8(b) are $\omega$ versus $N_s$ plots. The solid lines in these figures correspond to the following equations:
Fig. 5.7(a) Variation of $\langle D(\tau) \rangle$ as a function of $N_s$ for $^{12}$C-Em interactions. (b) $\Omega$ versus $N_s$ plot. The solid curve is the best fit of the data using Eq. (5.5).
Fig. 5.8(a) Variation of $\langle D(\eta) \rangle$ versus $N_\xi$ for $^{28}\text{Si-Ke}$ interactions.  
(b) $\varpi$ versus $N_\xi$ plot. The solid curve is the best of Eq. (5.6) to the data.
\[ \omega = (0.80 \pm 0.09) N_s (0.60 \pm 0.20) \quad (5.5) \]

\[ \omega = (0.98 \pm 0.08) N_s (0.69 \pm 0.24) \quad (5.6) \]

Eqs. (5.5) and (5.6) correspond to the best fits to the data for carbon- and silicon-emulsion interactions respectively.

The multiperipheral model predicts that \( \omega \) and \( N_s \) should satisfy the following relationship:

\[ \omega \propto N_s^{-1/2} \quad (5.7) \]

We have compared the results of the present study with the predictions of the multiperipheral model and find that the two results are in reasonable agreement with each other. This shows that the particles, especially at high multiplicities, might be emitted via cluster formation under multiperipheral scheme.

5.4 Shower width distribution

The shower width of an event is calculated using the following relation:

\[ R = \eta_H - \eta_L \quad (5.8) \]

where \( \eta_H \) and \( \eta_L \) are respectively the maximum and the minimum pseudorapidity values in an event. The shower width distributions for carbon- and silicon-emulsion interactions are shown in Fig. 5.9. It may be seen from the figure that the peak of the distribution slightly shifts towards a lower value of \( R \) as the projectile mass decreases. It is also observed in the figure that the space occupied by the charged shower particles in silicon-emulsion interactions is comparatively larger than those occupied by the charged
Fig. 5.9 Shower width distributions in carbon- and silicon-emulsion interactions at 4.5 A GeV.
secondaries in carbon-emulsion collisions. The shower width distributions for various $N_g$-bins for carbon and silicon projectiles are displayed in Fig.5.10. It may be noticed in the figure that the peaks of the $R$-distributions shift towards higher values of $R$ with increasing projectile mass. The shifting of the peaks of the $R$-distributions towards higher values of $R$ with increasing projectile mass can be explained in the light of the fact that the shower particles produced with larger angles would tend to appear in the target fragmentation region with increasing projectile mass.

5.5 Mechanism of cluster formation

During the recent years, several attempts have been made to investigate the mechanism of multi-hadron production in high energy hadron-hadron[9-12], hadron-nucleus[13-15] and nucleus-nucleus[16,17] collisions. The idea of the cluster formation in the intermediate stage of multiparticle production in high energy hadronic interactions has attained wide acceptability. It has been experimentally observed[18] that the fast pions produced in an interaction are correlated amongst themselves. The observed correlations amongst the secondary pions may be attributed to the double step mechanism; i.e., subsequent to a collision, massive hadronic systems, like clusters, resonances or fire-balls are formed which finally decay into the real physical particles. It is interesting to mention that some useful and significant information regarding particle production through the decay of clusters may be gleaned by examining the behaviour of the
Fig. 5.10 Shower width distributions in various $N_g$-bins for carbon- and silicon-emulsion interactions.
distribution of the rapidity difference between the nth nearest neighbours.

5.5.1 Rapidity-gap correlation

In order to examine n-particle correlations, the charged shower particles in each event are arranged in the decreasing order of their pseudorapidity values and the differences between the consecutive particles are calculated. Several investigators[9-18] have reported that the rapidity difference distributions in high energy hadron-hadron, hadron-nucleus and nucleus-nucleus interactions may be represented satisfactorily by the two-channel generalization of the Snider model[11]. According to the model, the rapidity density may be expressed as

\[ \frac{dn}{dr} = A \exp(-Br) + C \exp(-Dr) \]  

(5.9)

where A, B, C, and D are constants and \( \frac{dn}{dr} \) represents the cluster density. The first and the second terms of Eq.(5.9) correspond respectively to the short- and the long-range correlations.

Rapidity-gap distributions between adjacent charged shower particles for carbon- and silicon-emulsion interactions are shown in Fig. 5.11. A sharp and clear peak at a relatively smaller value of rapidity-gap is observed in Fig.5.11, indicating thereby the presence of two-particle correlations. The theoretical curve in the figure represented by solid line is drawn by using Eq.(5.9) for the data on silicon-emulsion interactions. It may be mentioned that in order to avoid confusion, the curve corresponding to
Fig. 5.11 Two-particle rapidity-gap distributions for carbon and silicon projectiles. The solid curve is drawn using Eq. (5.9).
Eq.(5.9) for carbon-emulsion collisions is not shown in the same figure. The dash-dot lines in the figure are the individual contributions of the two exponential terms. It may be noticed from the figure that the dash-dot line representing the contribution of the short-range correlation almost coincides with the solid curve in the region of lower values of the rapidity-gaps, whilst the dash-dot line representing the contribution of the long-range correlation is significantly far away from the solid curve in the region of lower rapidity-gap values. This indicates that the major contribution to the two-particle correlation comes from the short-range correlation, while the contribution of the long-range correlation appears to be rather small.

The values of the parameters A, B, C, and D occurring in Eq.(5.9) are computed with the help of the CERN standard programme MINUIT and the errors as given in MINOS. The values of these parameters are tabulated in Table 5.1 along with the values of $\bar{p}/DF$, where DF represents the degree of freedom. On comparing the values of the parameter B and D obtained for $^{12}$C- and $^{28}$Si-emulsion collisions at 4.5 GeV per nucleon, the values of these parameters are observed to be practically insensitive to the projectile mass. Incidentally, the values of these parameters compare fairly well with those reported[14,15] for hadron-nucleus interactions at high energies. Hence, it may be stated that the mechanism of multiparticle production in hadron-nucleus and nucleus-nucleus collisions are probably the same.
Table 5.1: Values of various parameters occurring in Eq. (5.9) for \(^{12}\text{C-}\) and \(^{28}\text{Si-Em}\) interactions at 4.5 A GeV.

<table>
<thead>
<tr>
<th>Projectile</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>(\chi^2/DF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{12}\text{C})</td>
<td>2.38±2.17</td>
<td>6.52±1.31</td>
<td>0.55±0.02</td>
<td>2.08±1.19</td>
<td>0.09</td>
</tr>
<tr>
<td>(^{28}\text{Si})</td>
<td>4.72±4.31</td>
<td>6.55±1.96</td>
<td>0.48±0.02</td>
<td>2.23±0.46</td>
<td>0.13</td>
</tr>
</tbody>
</table>
5.5.2 Rapidity-gap correlation in different $N_g$-intervals

For examining the dependence of the cluster size on the grey particle multiplicity, $N_g$, the data are divided into different $N_g$-intervals, i.e., $N_g = 0, 1, 2-3, 4-5, 6-8$ and $\geq 9$.

Rapidity-gap distributions between adjacent charged shower particles for various $N_g$-intervals for carbon- and silicon-emulsion interactions are exhibited in Fig.5.12. The occurrence of clear and distinct peaks at relatively smaller values of the rapidity-gaps, would indicate the existence of two-particle correlation.

The solid curves in Fig.5.12 correspond to Eq. (5.9) for the silicon-emulsion interaction data. It may be seen from the figure that the contribution of the short-range correlation is comparatively more in comparison to the long-range correlation. The values of the parameters $A$, $B$, $C$, and $D$ occurring in Eq. (5.9) for all $N_g$-intervals for carbon and silicon projectiles are listed in Table 5.2 along with the values of $\chi^2/DF$ for each fit.

5.5.3 Cluster size

The rapidity-gap distributions can also be used to estimate the cluster size and the cluster density in the rapidity space. The cluster size can be determined by using the following equations[19]

\[
\frac{dn}{dr} \propto \exp(- \rho mr) \quad \text{for small values of } r
\]

\[
\frac{dn}{dr} \propto \exp(- \rho r) \quad \text{for large values of } r
\]
Fig. 5.12 Two-particle rapidity-gap distributions for different $N_g$-intervals in carbon- and silicon-nucleus interactions. The solid curves are drawn using Eq. (5.9).
Table 5.2: Values of various parameters occurring in Eq.(5.9) for different $N_g$-intervals in $^{12}$C- and $^{28}$Si-nucleus interactions at 4.5 A GeV.

<table>
<thead>
<tr>
<th>$N_g$-bins</th>
<th>Carbon</th>
<th>Silicon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>$N_g=0$</td>
<td>1.54±1.38</td>
<td>5.23±1.34</td>
</tr>
<tr>
<td>$N_g=1$</td>
<td>1.50±1.21</td>
<td>9.00±4.17</td>
</tr>
<tr>
<td>$N_g=2,3$</td>
<td>2.92±1.79</td>
<td>3.79±2.63</td>
</tr>
<tr>
<td>$N_g=4,5$</td>
<td>2.87±1.62</td>
<td>5.78±1.70</td>
</tr>
<tr>
<td>$N_g=6-8$</td>
<td>4.81±4.35</td>
<td>7.59±2.44</td>
</tr>
<tr>
<td>$N_g &gt; 9$</td>
<td>3.36±2.15</td>
<td>6.09±2.11</td>
</tr>
</tbody>
</table>
where $p$ is the cluster density and $m$ is known as the cluster multiplicity, defined as the number of showers in a cluster. The values of $m$, calculated using Eq.(5.10) for carbon- and silicon-emulsion interactions for all the events and for different $N_g$-intervals are listed in Table 5.3. The results obtained in the present study agree fairly well with the predicted value of $m$ equal to 3.50 for 200 GeV pp interactions[11]. It is interesting to note that Ludlam and Slansky[20] have reported the value of $m$ equal to $4.0\pm0.8$ at 205 GeV/c and $3.5\pm0.8$ at 300 GeV/c by the fluctuation and analysis method. Thus, these results tend to reveal that the cluster multiplicity is independent of the nature of the projectile.

5.5.4 Short- and long-range correlations

According to Snider[11], if more than two charged particles result from the same cluster, then two consecutive short-gaps would occur in the rapidity space. Following Snider's suggestion, a small gap is defined to have $r_i < 0.1$ and a large gap should satisfy the condition $0.8 < r_i < 1.0$. For testing the validity of this idea, the behaviour of the distributions of the gaps occurring next to the short- and the long-gaps ($r_{i+1}$) are examined separately for both carbon- and silicon-emulsion interactions. These distributions are plotted in Figs.5.13 and 5.14 for the gaps occurring next to the short- and the long-gaps. Clear and distinct peaks are observed at relatively lower values of $r_{i+1}$. The solid curve in the distribution of the gaps occurring next to the short-
Table 5.3: Values of cluster multiplicity occurring in Eq. (5.10) for carbon and silicon projectiles at 4.5 A GeV.

<table>
<thead>
<tr>
<th></th>
<th>Carbon</th>
<th>Silicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>all events</td>
<td>3.13</td>
<td>2.94</td>
</tr>
<tr>
<td>$N_g=0$</td>
<td>3.41</td>
<td>3.84</td>
</tr>
<tr>
<td>$N_g=1$</td>
<td>4.20</td>
<td>3.85</td>
</tr>
<tr>
<td>$N_g=2,3$</td>
<td>2.92</td>
<td>4.15</td>
</tr>
<tr>
<td>$N_g=4,5$</td>
<td>3.61</td>
<td>3.10</td>
</tr>
<tr>
<td>$N_g=6-8$</td>
<td>3.95</td>
<td>3.50</td>
</tr>
<tr>
<td>$N_g &gt; 9$</td>
<td>3.00</td>
<td>3.81</td>
</tr>
</tbody>
</table>
Fig. 5.13 Distributions of rapidity gaps ($r_{i+1}$) next to a small gap ($r_i < 0.1$). The solid curve is drawn using Eq. (5.12).
Fig. 5.14 Distributions of rapidity gaps ($r_{i+1}$) next to a large gap ($0.8 \leq r_i \leq 1.0$).
gaps for silicon-emulsion interactions is represented by the following relation:

\[
\frac{dn}{dr_i+1} = (4.19\pm2.26) \exp(-5.66\pm1.03) r_i+1 + \\
(0.01\pm0.007) \exp(-0.83\pm0.25) r_i+1
\] (5.12)

and for carbon-emulsion collisions the following expression reproduces the data points well:

\[
\frac{dn}{dr_i+1} = (3.60\pm3.80) \exp(-5.33\pm5.65) r_i+1 + \\
(0.59\pm1.01) \exp(-1.97\pm2.54) r_i+1
\] (5.13)

The lines drawn by dashes and dots in Fig. 5.13 are the contributions of the short-short and the short-long correlations. It may also be noted in Fig. 5.13 that a major contribution to the correlation comes from the short-short correlation. Furthermore, it may be mentioned that the values of B are essentially the same for both carbon and silicon projectiles.

5.5.5 Production of heavy clusters

Adamovich et al[19] have proposed a method for investigating the production mechanism of the heavy clusters in the interactions with charged shower particle multiplicity, \( N_s \), nearly equal to the mean charged shower particle multiplicity, \( \langle N_s \rangle \), for the whole data. The rapidity interval \( \eta_{rk} \) is defined as the difference of the rapidities of two particles in an event having \( n \) shower particles with \( k \) particles in between as:

\[
\eta_{rk} = \eta_{i+k-1} - \eta_i
\] (5.14)

with \( 1 \leq i \leq n-k-1 \) and \( 0 \leq k \leq n-2 \).
In the present work, the values of $\langle N_s \rangle$ are found to be 7.67±0.19 and 11.26±0.33 for carbon- and silicon-nucleus collisions respectively.

123 carbon-nucleus interactions having $N_s = 7$, 8 and 9 and 93 silicon-nucleus interactions having $N_s = 10$, 11 and 12 were selected for the present analysis giving 993 and 999 shower tracks respectively for $^{12}$C- and $^{28}$Si-emulsion interactions.

According to Adamovich et al[19], the production of the fire-ball types of heavy clusters should manifest its effect most significantly in the distributions having $k \geq N_s/2$. In the present study, the values of $\langle N_s \rangle$ are approximately equal to 8 and 11 for carbon- and silicon-emulsion collisions respectively. Therefore, the presence of two-bump structures should occur in the distributions for $k \geq 4$ and $k \geq 5$ for carbon- and silicon-emulsion interactions, respectively. The distribution of the rapidity-gaps $r_k$ for $k = 0$ to 7 and $k = 0$ to 10 for carbon- and silicon-nucleus interactions are shown in Figs. 5.15 and 5.16. From the figures, it is evident that there is no evidence for the occurrence of two-bump structure for the two cases. However, Goyal et al[21] have obtained very clear evidence for the production of heavy clusters in nucleon-nucleon interactions at cosmic ray energies ~ 1000 GeV. Recently, Bell et al[22] and Andersson et al[23] have reported the production of heavy clusters in $\alpha-\alpha$, p-p and d-d interactions at ISR energies.
Fig. 5.15 Experimental distributions of rapidity intervals $n_{r_k}$ with $k = 0$ to 7 for carbon-emulsion interactions.
Fig. 5.16 Experimental distributions of rapidity interval $n_{r_k}$ with $k = 0$ to 10 for silicon-nucleus interactions.
6.8 Conclusions

From the above detailed investigation concerning the features of pseudorapidity and the clusters of particles produced in $^{12}\text{C}$- and $^{28}\text{Si}$-emulsion collisions, the following main conclusions can be drawn:

1. The shape of $\eta$-spectrum is almost independent of the projectile mass.

2. The behaviour of the $\eta$-spectra for different effective target thicknesses are in good accord with the predictions of the coherent tube model.

3. The value of $<\eta>$ decreases monotonically with increasing $N_\gamma$, $N_\pi$ and $N_h$.

4. The distribution of the rapidity dispersion clearly shows the occurrence of clusterization in carbon- and silicon-nucleus interactions.

5. The variation of $<D(\eta)>$ with the corresponding number of the charged shower particles is found to be constant, except, in the region of small $N_\pi$ values. This indicates that a large part of the cross-section is contributed by the peripheral collisions with one intranuclear nucleon.

6. The maximum of the shower width distribution shifts towards slightly higher values of $R$ with increasing projectile mass. This reveals that the shower particles are produced at larger angles as the projectile mass increases.

7. Mechanism of multiple production of particles in nucleus-nucleus and hadron-nucleus interactions are perhaps the same.

8. The cluster size is independent of the nature and the
energy of the projectile.

(9) The contribution of the short-range correlation is larger in comparison to the long-range correlation for both the projectiles.

(10) Two-bump structure has not been observed in both carbon- and silicon-emulsion interactions which reveals that the heavy clusters are not produced in these interactions.
References

7. Y. Afek et al: Topical meeting on multiparticle production on nuclei at very high energies, Trieste (1976).