CHAPTER VI
SUMMARY AND CONCLUDING REMARKS
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The prime objective of the present investigation was to study the fluctuation, both in spatial as well as charge distribution of projectile fragments to realize the signature of liquid-gas phase transition.

The nuclear multifragmentation phenomenon was predicted and studied since the early 80's. It is however only with the advent of powerful 4π detectors that real advances had been achieved only recently. Such arrays of detectors allow the detection of a large amount of fragments and light particles produced in nuclear collisions at intermediate and high energies. The Equation of State describing nuclear matter, similar to the Van der Waals equation for classical fluids, foresees the existence of a liquid-gas type phase transition; multifragmentation was long-assimilated to this transition. The dominant role played by surface and Coulomb energy on multifragmentation mechanism has extensively been studied in the recent past. In this work an attempt was made to show the system size dependences on multifragmentation data, due to the interplay of surface and Coulomb free energies of the fragmenting system.

The fragmentation of relativistic nuclei is a source of information about their structure. Both the participant and spectator are relevant for studying the nuclear collision dynamics. Since nuclear emulsion is a global 4π detector and has the best spatial resolution (about 0.1 m rad) among all the detectors currently in use in high energy physics, this technique has been found to be an important tool particularly to study those properties which are related to the spatial distribution of the emitted particles. Intermittency in the emission spectra of high energy A+A collision is one such property. Until now, no result has so far been reported on the studies of fluctuation in the spatial distribution of PFs due to the difficulties of the measurement of PF angle. In the present investigation an attempt was made to study the fluctuations in the emission spectra of projectile fragments in terms of Scaled Factorial Moments (SFM) and generalized moments. Multiplicity characteristics of various charged projectile fragments has also been studied for the present multifragmentation data of 4.5 AGeV $^{24}$Mg-Em interaction.
From this experimental work the mean multiplicity of all the projectile fragments for the entire data sample of present investigation on $^{24}$Mg-Em interactions at 4.5 AGeV is found to be $2.76 \pm 0.37$. The mean multiplicities of projectile fragments with $Z_{PF} = 1$, $Z_{PF} = 2$ and $Z_{PF} \geq 3$ are found to be $1.57 \pm 0.1$, $0.89 \pm 0.09$ and $0.47 \pm 0.11$ respectively. The normalized multiplicity distribution of projectile fragments reveals that the number of events with no $Z_{PF} = q$ where $q=1, 2, 3...$is more than the number of events with a particular $Z_{PF}$. Such observations are found to consistent with the results reported by other workers for lighter projectile like $^{28}$Si, but inconsistent with the results reported for heavier system like $^{197}$Au and $^{238}$U.

The projectile mass is found to have strong influence on the mean multiplicities of various charged secondaries emitted from high energy A+A collisions. However, a more strong correlation could be observed for smaller systems.

The average number of produced particles, fast protons and evaporated particles as well as the heavily ionizing fragments are found to decrease exponentially with $Q_{pf}$, that is, as one goes from central to peripheral collisions.

Correlation between average number of IMFs and the mass of the fragmenting system is one of the most interesting aspects of studying projectile fragmentation. For a given colliding system, the magnitude of $Z_b$ is independent of the beam energy and is also taken as a measure of the degree of centrality of the collision. It is found that the production of heavy and intermediate mass fragments is a function of the size of the fragmenting system. Light, intermediate and heavy charge projectile fragments such as $Z_{PF} = 1 & 2$ and $\geq 3$ show strong dependence on mass number of projectiles of similar energies. A systematic decrease in the system size has also been observed for the present multifragmentation data when compared with the results of other workers.

The horizontally averaged scaled factorial moment (SFM) analysis for spatial distribution of projectile fragments exhibits a power law behaviour with decreasing phase space bin size of the type $<F_q> \propto M^{\alpha_q}$, where $M$ is the number of
bins in which a given pseudorapidity interval is divided. This thereby indicates an intermittent pattern in the emission of projectile fragments. Similar investigation of SFM on the size of the projectile fragments reveals a power law growth of $< F_q >$ on bin width $\delta s$, of PF charge(mass).

The different values of the exponents $\phi_q$, called intermittency indices, representing the strength of the intermittency signal, are found to increase with the order of moments for both the spatial and charge distributions of projectile fragments.

The anomalous dimension $d_q = \phi_q / (q-1)$ is found to increase linearly with the order of the moments ‘q’ for both the analyses, thereby indicating the multifractal structure for single particle density spectrum.

To study the fractal behaviour of the multiplicity fluctuation, $^{24}\text{Mg} - \text{Em}$ interactions data are investigated using the multifractal moments, $G_q$ as a function of phase space bin size $M$ for the emission spectra of the projectile fragments. $<G_q>$ shows a power law dependence on the phase space bin size of the form $<G_q> \propto M^{-d_q}$, thereby indicating fractal nature of the emission spectra of projectile fragments. Similarly for the charge distribution of projectile fragments, the $G_q$ moment have been found to follow a power law of the form $<G_q> \propto (\delta s)^\gamma$.

The fractal indices $\tau_q$ or the experimental data points and $\tau_q^{\text{gen}}$ for the generated events are obtained from the slopes of the best fitted lines of the respective analyses. A clear deviation of $\tau_q^{\text{gen}}$ from q-1 as obtained for the present experimental data points for single particle density and charge distribution clearly indicates that $<G_q>$ contains dynamical information.

The generalized dimension $D_q$ characterizing the extent of disorderness of the fractal object have been estimated for different order of moments for the emission spectra as well as for the charge distribution of projectile fragments with $\chi(\eta)$ and $Z_{PF}$ as phase space variable. The variation of $D_q$ with $q = 2 - 4$ show that $D_q$ decreases linearly with $q$ in either cases. This is considered to be a signature of the association of multifractality in both the emission spectra of projectile fragments.
from $^{24}$Mg - Em interactions at energy of 4.5 AGeV.

The intermittent behaviour in the final state of multiparticle production in relativistic nuclear collisions may be a projection of the occurrence of a non thermal phase transition. This aspect is investigated in terms of behaviour of $\lambda_q = (\phi_q + 1)/q$. In the present study, for the interactions of $^{24}$Mg nuclei with emulsion, no distinct minimum has been observed for $\lambda_q$ versus $q$ plot for the spatial distribution of projectile fragments, whereas for the charge distribution of projectile fragments, a distinct minimum has been observed. The observed minimum may be an indication for the occurrence of a non-thermal phase transition in the charge distribution of projectile fragments for the collisions.

The occurrence of non-thermal phase transition in the charge distribution of projectile fragments indicated the relevance of further analysing the gathered data in the light of criticality and possible liquid to gas phase transition.

From the cluster approximation technique analysis of the data of present investigation, a clear rise and fall pattern could be observed in the size of the largest cluster and the second moment of charge distribution. Such rise and fall pattern of these observables have been traditionally accepted as the signature of critical behaviour in nuclear matter. A comparison of the results of this work with the results of earlier works of GU group on Kr-Em and EOS data on Kr, La and Au interactions with C reveal clear evidences of system size dependences on multifragmentation mechanism.