Preface

The history of heavy-ion physics dates back to the early 1970's, when a group of physicists at the Lawrence Berkeley Laboratory (LBL) used the Bevalac facility to study shock compression within nuclear matter. Since that time the scope of the subject has expanded enormously, with many different issues emerging and new dimensions continuously being added to them. During the past three decades or so, technology has allowed us to construct bigger accelerators capable of producing ions moving with ultra-relativistic speed, and the focus of heavy-ion physics has also shifted to a large extent. At present, the subject stands at the interface between nuclear and particle physics, whose central research objective is to create and characterize a new state of matter comprised of isolated quarks and gluons within a limited region of space-time. This new state is similar to the ordinary plasma in the sense that, like free electrical charges in the latter, colour degrees of freedom can break loose out of their usual confinement within hadrons, in the former. However, this can be achieved only if local thermal equilibrium is established. Indications from the latest RHIC results are strongly in favour. People call it the Quark-gluon Plasma (QGP), a state that perhaps filled up the universe only after a few micro-seconds after its birth, may still be available at the core of very compact stars, and may possibly be created in the laboratory by colliding two nuclei at high-energy. Over the period of time for which high-energy heavy-ion physics has been seriously taken as a frontier area of research, there have been claims and counter claims about the formation and observation of such an exotic state of matter in the laboratory. However, it is safe only to say that the situation is far from conclusive, and with the installation of the Large Hadron Collider (LHC) at CERN (Geneva), we are probably standing at the doorstep of achieving the ultimate goal of QGP creation under the controlled conditions of a laboratory.

A relativistic heavy-ion collision is a dynamical process that takes place within a typical space-time scale of 10 fm. A state like the QGP, even if it is created, cools down vary rapidly to undergo a QCD phase transition and fragments into colour neutral hadrons, several other species of particles and radiation. One has to critically examine these remnants of the interaction, and undertake the tedious journey to trace back history to the initial stage of the collision. It's tempting to draw a parallel with the "big bang" theory of the birth of our universe and its connection with the observation of cosmic microwave background. Often therefore, a high-energy collision between two nuclei in laboratory is termed as a "little bang".

Beside the fact that in a high-energy interaction two colliding nuclei fragment into smaller pieces, many new particles are also produced. To the physicists working in this area the mechanism of multiparticle production has remained a topic of investigation for a long period of time. For this purpose it is necessary to analyze the distributions of these particles in terms of their number, energy, momentum, rapidity etc.. However, it has also been a long tradition to perform such analysis, globally. During mid 80's the priorities changed drastically, and in stead of global distributions, local structures of particle distribution within limited regions of phase-space started to draw more attention. If the final state particles are an outcome of a phase transition, one expects various time integrated patterns of clusters within narrow regions of phase-space, as well as sharp voids in the distribution. This may also happen even without invoking any phase transition, as observed in normal hadronic interactions. As a result, sharply fluctuating phase-space distribution of particle densities should be observed. On many occasions the study of fluctuations in physical variables (or quantities) has initiated new frontiers of scientific research. However, it's absolutely essential to figure out whether the fluctuations arise out of trivial statistical noise, or do they have any dynamical origin. Various statistical methods to study the dynamical component of fluctuation in multiparticle distribution have been suggested. Efforts have been made to associate self-similar geometrical structure, like fractals, to the observed fluctuations. In the present investigation we have collected and analyzed a set of data on the angular distribution of singly charged particles produced in ^{32}S-Ag/Br interactions at an incident momentum of 200A GeV/c. Nuclear emulsion technique has been employed to collect the data, and the data have been analyzed in terms of the intermittency, multifractality and erraticity techniques. Over the past two decades the validity of these statistical methods, suggested by others, has been tested on several other data sets on high-energy interaction. We do not claim any originality regarding the data analysis techniques adopted in the present investigation.

The thesis starts with a brief review of the subject namely, nucleus-nucleus (AB) interaction at high-energy. We have tried to emphasize the broad experimental aspects of the subject, avoiding mathematical intricacies as they do not fall within the scope of present investigation. While organizing chapter one, the following sequence has been maintained. Salient features of two body kinematics, the roll of geometry in collision between two nuclei, and some other general characteristics of AB interaction have been outlined. A semi-qualitative description of the space-time evolution of AB interaction in terms of Landau's and Bjorken's hydrodynamical models has been incorporated. Deconfinement of colour degree of freedom and formation of QGP in AB interaction has been discussed in terms of the MIT Bag model. Both the high temperature and high pressure scenario have been addressed. Thereafter, the experimental status of AB interactions at high-energy has been described. We have concentrated mainly on experiments performed during the BNL-AGS, CERN-SPS and BNL-RHIC era. The physics of various signatures that have already been suggested to identify the creation of a QGP like state has been outlined, and the major experimental observations corresponding to each of these signatures have been depicted. As the present investigation mainly deals with fluctuation in particle number within narrow intervals of phase-space, the phenomenological and experimental issues related to this particular area have been elaborated with a little more details than the other signatures. The first chapter ends with a brief qualitative description of several models on particle production in high-energy AB collision.

Chapter two is a compilation of three different aspects namely, the nuclear emulsion technique, the microscopy associated with it, and some gross features of the data sample used. Since 1940's the nuclear emulsion has remained as an accepted technique for studying interaction between particles. Beside its low cost and easy to handle properties, the unique feature that makes nuclear emulsion still a useful tool, is its high spatial resolution. Particularly if one is trying to investigate the structure of particle distribution within narrow spatial intervals, then nuclear emulsion can certainly be a preferred choice over its costlier, larger and more glamorous electronic counterparts. However, the technique also has certain limitations. With the collider type of experiments becoming more and more dominant over the fixed target ones, it's probably not a very distant future when the application nuclear emulsion technique is going to be limited only to cosmic ray experiments. In chapter two we have tried to address most of the important issues pertaining to nuclear emulsion and its associated microscopy. This chapter also includes a section covering certain kinematic, and statistical features of the ^{32}S-emulsion data sample used for further analysis and presented in subsequent chapters. This is important, because it provides the reader with a fair idea about where do our results stand with respect to those obtained from similar other investigations.

In chapter three, four and five, issues related respectively to intermittency, multifractality and erraticity have been discussed, and our results on these three different aspects of particle production have been described. There are certain common features among these apparently differing phenomena. All three techniques involve studying fluctuation of produced particle density in limited phase-space intervals. In each of them, one type of power law scaling behaviour or the other has been used. The scaling laws describe variations of certain moments of particle distribution as functions of phase-space interval size. There also exist close connections between intermittency and multifractality, as well as that between intermittency and erraticity. In the first case, several intermittency and multifractal parameters that result from the corresponding scaling law, can be related to one another as both the phenomena deals with the same underlying self-similar structure of particle distribution. Whereas in the second case, the erraticity technique analyzes the event-to-event fluctuation of fluctuation of particle density in a single event the latter being characterized by the moments of intermittency. We have tried to make our analysis as comprehensive as possible, but scopes of improvement are not ruled out. The thesis ends with a short summary of the major conclusions of the present investigation, with a few remarks on what else can be done in future.

I would like to end this preface with some personal remarks. It was October 2001 when as a Junior Research Fellow, I started to work in the field of high-energy heavy-ion interaction in the Department of Physics of the University of North Bengal. For the past six years or so, we tried to utilize our limited resources, and could ultimately bring the thesis out in its present form. The thesis is based mainly on the works published in the following papers by our group:

1. Erraticity analysis of particle production in ^{32}S-Ag/Br interaction at 200A GeV/c - Malay Kumar Ghosh and Amitabha Mukhopadhyay, Physical Review **C 68,** 034907 (2003).

2. Erraticity analysis of multiparticle production in nucleus-nucleus interactions at relativistic energies - Dipesh Chanda, Malay Kumar Ghosh, Amitabha Mukhopadhyay and

Gurmukh Singh, Physical Review **C 71**, 034904 (2005).

3. Multifractal moments of particles produced in ^{32}S-Ag/Br interaction at 200A GeV/c - Malay Kumar Ghosh, Amitabha Mukhopadhyay and Gurmukh Singh, Journal of Physics G: Nuclear and Particle Physics **32**, 2293 (2006).

4. Intermittency and mutiplicity moments of charged particles produced in ^{32}S-Ag/Br interaction at 200A GeV/c - Malay Kumar Ghosh, Amitabha Mukhopadhyay and Gurmukh Singh, Journal of Physics G: Nuclear and Particle Physics **34**, 177 (2007).

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