Study of Fluctuations in Ginzburg- Landau Model

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1. Introduction

Investigation of phase transitions is a conventional study in statistical physical described by Ginzburg- Landau Model. In analogy the same is extended to the study of multiparticle production in high energy collisions, the understanding of which involves study of intermittency (fluctuations) and their behaviour with respect to Quark-Gluon Plasma and first/second order phase transitions are understood accordingly [1-3].

The motivation for studying relativistic heavy ion collisions is to gain understanding of equation of state of nuclear, hadronic and partonic matter commonly referred to as nuclear matter. The behaviour of nuclear matter as function of temperature and density (or pressure) is governed by its equation of state. Here normal nuclei exist and at low excitation a liquid-gas phase transition is expected to occur. This is the form of experimental studies using low energy heavy ions. This region is presently accessible in heavy ion studies at the AGS accelerator facility at Brookhaven National Laboratory (BNL) and the Super Proton Synchrotron (SPS) accelerator facility at CERN. There may be possibility that some part of these collisions traverse the transition region into the quark-gluon plasma region. Formation of quark-gluon plasma, a deconfined state of quarks and gluons is presently the major focus of relativistic heavy ion experiment at higher energies. For this purpose the relativities heavy ion collider (RHIC) [4-6] and associated experiments are performed under construction at Brookhaven for operation in 1999 and operation with heavy ion planned for the Large Hadron Collider in 2005.

2. Mathematical Formulation

Consider a small cell in phase space with size δ. Here δ is an interval of a one-dimensional variable such as rapidity δη or that of three-dimensional space. In Ginzburg- Landau description [7-9] of phase transitions, the factorial moments F_q are given by

$$F_q(\delta) = Z^{-1} \int D_\phi \, \phi^{2q} \, \delta^q \exp(- F[\phi]) \qquad (1)$$

Where Z is partition function, F [ϕ] is the free energy function of the system in the cell δm and ϕ described the probability that the system is in a pure state [ϕ] . In the general theory of phase transition.

$$F[\phi] = \delta[a(T - T_c)[\phi]^2 + b[\phi]^4 + c[\phi]^6] \qquad (2)$$

$$H_q(\mathrm{v}) = \int_0^\infty dy\, y^q \exp(-y^2 + \mathrm{u}v^2\, \mathrm{y} + \mathrm{v}y^2) \qquad (3)$$

Thus v > 0 corresponds to first order phase transition and v < 0 corresponds to a second order phase transition. With this definition, the Scaled Factorial Moments

$$F_q(\delta) = \frac{f_q(\delta)}{[f_1(\delta)]^q} \qquad (4)$$

Scaled Factorial Moments can be expressed as a function

$$lnF_q = (q-1)\ln\left(\frac{H_o}{H_1}\right) + \ln\left(\frac{H_o}{H_1}\right) \qquad (5)$$

The Scaled Factorial Moments [9] F_q were first proposed to eliminate the statistical fluctuations. From the above relations, one can calculate the Scaled Factorial Moments as a function of resolution δ.

$$H_q(\mathrm{v}) = \sum_0^\infty a_{q,k}\; v^k \qquad (6)$$

where

$$a_{q,k} = \frac{1}{3}\sum_{m,n>0}^{2m+n=k} \frac{u^m}{m!n!}\, \Gamma\left(\frac{m+2n+q+1}{3}\right)$$

3. WA98 EXPERIMENT

A high granularity Preshower Photon multiplicity Detector as a part of CERN International hybrid experiment WA98 collaboration is mainly used for these studies. The sophisticated online nuclear detector PMD uses scintillating plastics as the radiation sensitive material and lead sheets of three radiation length as the converter for the development of the electromagnetic shower. The readout signal after pedestal correction is subjected to cluster algorithm to count for gamma-like clusters [10]. The output of experiments is the photon multiplicity with pseudorapidity coverage $2.5 \leq \eta \leq 4.2$ of which $3.2 \leq \eta \leq 4.0$ has full azimuthal angular configurations. The detector has been designed, fabricated and assembled in India and installed at European Nuclear Research Centre (CERN) as a part of WA98 collaboration.

4. Calculations Tables

The analysis is made on central collisions only which are characterized by E_T cut of 348.8 GeV. From the sample of the interactions, we have collected 20062 central events. The quality of the events is tested for various plots like η-distribution and ϕ-distribution which are in line with the published results. For this purpose the VENUS 4.12 and GEANT (GWA98) package is used and the number of central collisions simulated was about 15342.The data is analysed in restricted pseudorapidity window $3.2 \leq \eta \leq 4.0$ with full azimuthal coverage. The distribution of particles in bins of different size ($\delta\eta$=0.1) from a given pseudorapidity. Window width ($\delta\eta$=0.8) is studied. The bin width of $\delta\eta$=0.1 is chosen constrained by resolution limits of experimental setup. In order to interpret the results of experimental distributions, simulation studies for an identical experimental set up was made. These events were also subjected to all the procedures laid down for the experimental data.

A relative comparison of the above studies was made for the relevant parameters and attempt has been made to understand the mechanism of the particle production and the observation of the fluctuations in the photon multiplicities in Pb-Pb collisions at 158 A GeV.

TABLE 1. The values $b_{q,0}$, $b_{q,1}$ and $b_{q,2}$ for q = 2, 3, 4

$b_{q,k}$	2	3	4
$b_{q,0}$	0.479	1.741	3.047
$b_{q,1}$	1.863	-0.585	0.031
$b_{q,2}$	-1.217	-0.921	-2.040

TABLE 2. The values of coefficients of A, B and C obtained from horizontal scaled factorial moment corrected for Experiment central data (polynomial fit).

$b_{q,k}$	2	3	4
$b_{q,0}$	0.03±0.02	0.05±0.04	0.23±0.06
$b_{q,1}$	0.04±0.09	0.07±0.14	0.54±0.01
$b_{q,2}$	0.03±0.09	0.05±0.14	0.44±0.01

TABLE 3. The values of coefficients of A, B and C obtained from horizontal scaled factorial moment corrected for simulated central data (polynomial fit).

$b_{q,k}$	2	3	4
$b_{q,0}$	0.03±0.01	0.05±0.03	0.14±0.03
$b_{q,1}$	0.04±0.05	0.07±0.07	0.44±0.08
$b_{q,2}$	0.03±0.06	0.05±0.08	0.35±0.07

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