Dynamical Fluctuations of Photon Multiplicities in Pb ion interactions at 158 A GeV

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Abstract. Non-statistical fluctuations in the multiplicities of charged particles and photons and the total transverse energy in 158 *A* GeV Pb+Pb collisions are studied for a wide range of centralities. The centrality dependence of the charged particle multiplicity fluctuations in the measured data has been found to agree reasonably well with those obtained from a participant model. 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. Such a situation is quite suitable for the formation of a deconfined state of matter known as hot Quark-Gluon Plasma (QGP) which subsequently cools and expands. In this process the energy density becomes low enough so as a phase transition Quark-Gluon Plasma (QGP) to hadrons state occurs.

Keywords: Charged particle in accelerators, Quark matter, Quark-Gluon Plasma (QGP), Heavy ions, Big Bang theory.
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1. Introduction

Non-Statistical fluctuations in high multiplicity events produced in relativistic particle-nucleus and nucleus-nucleus collisions have been extensively investigated by Takagi [1]. Miyamura and Tabuki [2] have also studied multiplicity distributions in different rapidity bins using scaled factorial moments F_q approach [3]. The bin size dependence of normalized factorial moments of the JACEE event [4] was analysed by Bialas and Peschanski [5]. However, approaches which are based on the concept of multi-fractals, appear to be the most promising as they are believed to be related to self-similar cascading, chaos, Phase transitions, etc; [6]. Some interesting results on intermittency and Multifractality have already been reported earlier [7-8]. The theory which at present is believed to the best description of strong forces is quantum chromodynamics (QCD). Phase Transitions has always been a subject of great interest in many fields. The theory which at present is believed to the best description of strong forces is quantum chromodynamics (QCD).

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 of phase transitions, the factorial moments F_q are given by

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

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.

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

$$H_q(v) = \int_0^\infty dy\, y^q \exp(-y^2 + uv^2 y + vy^2)$$

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

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

Scaled Factorial Moments can be expressed as a function

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

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 . 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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