Predictions for higher moments of Net-Charge and Net-Baryon from RHIC to LHC

N. K. Behera[1],* S. Jena[1], B. K. Nandi[1], and T. K. Nayak[2]
[1] *Indian Institute of Technology Bombay, Powai, Mumbai-400076, INDIA and*
[2] *Variable Energy Cyclotron Center, 1/AF, Bidhan Nagar, Kolkata-700064, INDIA*

Introduction

Mapping QCD phase diagram as a function of temperature (T) and baryo-chemical potential (μ_B) is one of the fundamental goal of heavy ion collision experiments. There are many theoretical predictions about critical phenomena like existence of critical point at large μ_B and chiral symmetry restoration at vanishing μ_B on the μ_B - T plane[1],[2]. To map the QCD phase diagram, we need to scan the QCD phase diagram by varying the initial collision energy. Lattice QCD can predict the freez-out parametrs very accurately at vanishing μ_B like at LHC energies. According to Lattice QCD calculation, the phase transition will be second order with chiral symmetry restoration at $\mu_B \sim 0$[3].

It has been argued that critical phenomena are signaled with increase and divergence of correlation length. In heavy ion collision experiments event-by-event observables like particle multiplicities, net charge, net baryon number, particle ratios and mean transverse momentum are sensitive to such phenomena[4]. It is expected that the higher derivatives of the QCD partition function with respect to temperature and μ_B will show it up and through the analysis of higher moments, more specifically the higher order cumulants of conserved quantities like net charge and net baryon and from the behavior of respective susceptibilities, one can gather information on possible nearby singularities in the QCD phase diagram[5]. The relation between $n-th$ order cumulants C_n with the susceptibility $\chi^{(n)}$ is as follow,

$$C_n = (VT^3)T^{n-4}\chi^{(n)}_{x,0} \qquad (1)$$

where the generalized quark number susceptibility $\chi^{(n)}_{x,0}$

$$\chi^{(n)}_{x,0} = \frac{\partial^n lnZ}{VT^3\partial(\mu_B/T)^n} \qquad (2)$$

evaluated at μ_B=0. where x = Q, B, S and Z is the partition function.

The mean (M), sigma (σ), skewness (S) and kurtosis (κ) of the distribution of net charge and net baryons are believed to be sensitive probes in fluctuation analysis. The dependence of $n-th$ order higher moments(cumulants) with the correlation length ξ is as follows [4].

$$C_n \sim \xi^{2.5n-3} \qquad (3)$$

Equation - 3 shows how the higher order cumulants are sensitive to ξ. Moreover, recent theoretical development suggest that the ratio of cumulants (volume independent quantities) like $S\sigma = C_3/C_2$, $\kappa\sigma^2 = C_4/C_2$ are useful to quantify the freeze-out parameters at RHIC and LHC[6]. Furthermore it is demonstrated that higher order cumulants will change their sign in the crossover region of the QCD phase diagram[7]. So it will be very interesting to study higher moments at top RHIC energy to LHC.

Analysis and Results

The net charge(proton) are calculated event-by-event basis within $|\eta|$ <0.8 and the transverse momentum range 0.3< p_T <1.5GeV/c^2. Mean(M), sigma(σ), skewness (S) and kurtosis (κ) are calculated as follows. M =

*Electronic address: nbehera@cern.ch

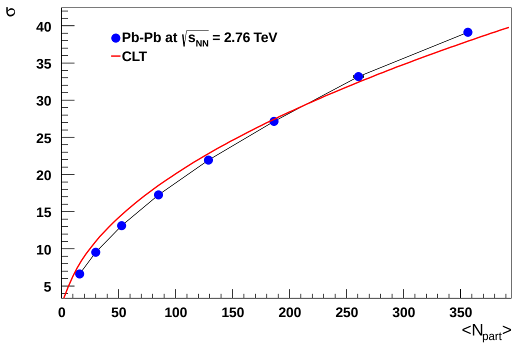

FIG. 1: σ of net-Charge distribution for different centralities fitted with CLT

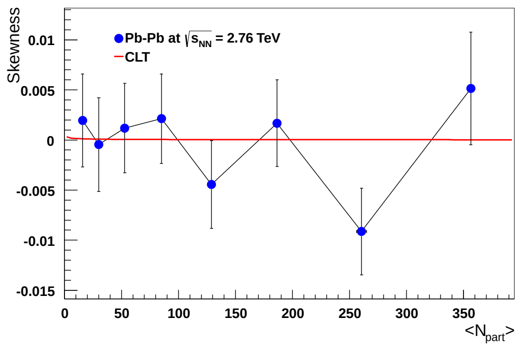

FIG. 2: Skewness of net-Charge distribution for different centralities fitted with CLT

$< \delta N >$, $\sigma = \sqrt{< (\delta N - < \delta N >)^2 >}$, $S = \frac{<(\delta N - <\delta N>)^3>}{\sigma^3}$, $\kappa = \frac{<(\delta N - <\delta N>)^4>}{\sigma^4} - 3$ where $\delta N = \sum N_+ - \sum N_-$. Figure - 1, 2 and 3 are σ, skewness and κ of net charge distribution at different centralities, respectively. The data points are fitted with the Central Limit Theorem (CLT)[8] after bin-width correction to remove fluctuation of collision impact parameter due to finite centrality bin width[9]. The errors are estimated by delta theorem as described in the ref[10]. In this presentation we will be showing the higher moments of net-charge and net-baryon numbers at RHIC and LHC energies by using different theoretical models.

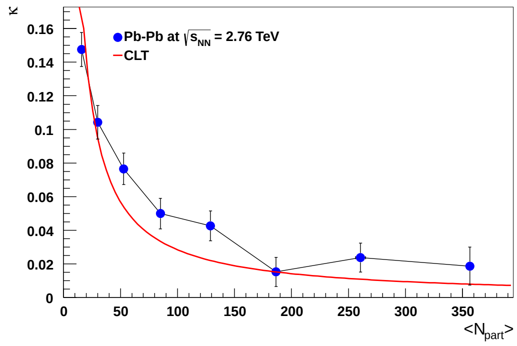

FIG. 3: Kurtosis of net-Charge distribution for different centralities fitted with CLT

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