Study of multiplicity distribution using Ginzberg-Landau model

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Introduction

One of the main reasons for studying high energy heavy ion collisions came from QCD prediction for possible manifestation of the phase transition in which a new phase of matter, quark gluon plasma (QGP), is produced. Although the exact nature of phase transition (whether first or second order) is still not known, the lattice results suggest that the phase transition at high temperature and low baryon density could be a simple cross over from QGP to hadron phase as contrast to a first order phase transition which is expected at low temperature and high baryon density. Consequently, it is natural to assume the existence of a critical end point (CEP) on the $\mu - T$ phase diagram that indicates a change from cross over to a first order transition. Recently, experiments are carried out at RHIC at various collision energies to search for the possible existence of CEP. While analyzing the data from PHENIX experiment at various energies for net-charge fluctuations, which could be a possible signature of phase transition, we developed a phenomenological model to interpret the results.

In the following, we discuss a generalized Ginzburg-Landau formalism of phase transition [1], which has been applied to explain the experimental total charge distribution of published PHENIX data at various collision energies [2]. This model which is applicable both for first and second order phase transition has been used earlier by Babichev [3] to explain the total charge distribution for Au+Au data at 130 GeV.

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The Model

The multiplicity distribution $P_n(\delta)$ can be written as

$$P_n(\delta) = \frac{S^n}{n!} Z^{-1} \int_0^\infty dy y^n e^{-y^3-(a+1)Sy-\sqrt{s}By^2} \tag{1}$$

with

$$Z = \int_0^\infty dy e^{-y^3-aSy-\sqrt{s}By^2}$$

Where $S = (\delta^2/c)^{1/3}$ and $B = b/\sqrt{c}$. In the above equation, a is negative for second order transitions, whereas in case of a first order transition a is negative or positive depending on whether $T < T_c$ or $T_c < T < T_t$. Apart from a, we have another two variables S and B, where S only depends on the bin size δ and B has the same sign as that of b. One can study the behavior of $P_n(\delta)$ at different temperatures with various B and S parameters. We have applied our model to PHENIX (0 - 5)% central collision data for $\sqrt{s_{NN}} = 22$ GeV and 200 GeV for Cu+Cu collisions and 62.4 GeV and 200 GeV for Au+Au collisions. The data points fitted with model are shown in Fig.1. The values of B, a and S are listed in the caption of Fig.1.

Conclusion

As shown in the figure, the model fits extremely well the experimental total charge distributions. Although the parameters of the model (B, a and S) are kept as free parameter to achieve the best fit, the important observation is the sign and the magnitude of the parameter B. As mentioned before, a positive or close to zero value of B would mean the transition is weakly first order or even could be a crossover, where as a large negative value is an indication of a strong first order phase

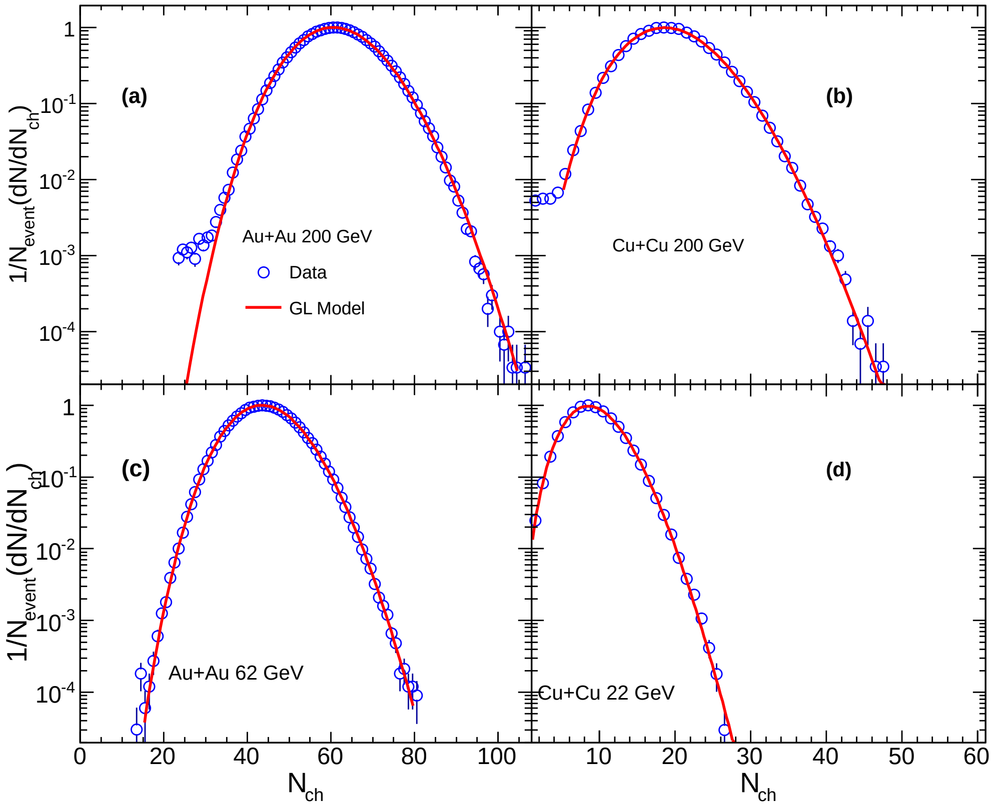

FIG. 1: The total charge distribution from PHENIX experiment [2] for different energies are shown in open symbols are fitted with the GL model shown in solid line. The fit parameters for (**a**) are: S = 17.35 ± 0.10, B = -0.10 and a = -1.91 ± 0.04, for (**b**) S = 13.36 ± 0.08, B = -0.30 and a = -1.80 ± 0.04, for (**c**) S = 9.34 ± 0.05, B = -0.1 and a = -1.08 ± 0.02 and for (**d**) S = 3.37 ± 0.07, B = -2.41 ± 0.01 and a = 1.09 ± 0.18

transition. Although the work is in progress, it could be possible to conclude from this analysis that measurement at 200 GeV may be a signature of a crossover transition and at 22 GeV the transition could be of first order. Therefore, it will be interesting to see if this model can be extended to estimate the various moments of both net and total charge distribution, which are important for the study CEP.

References

[1] A.K.Mohanty and S. Kataria, Phys. Rev. C **53**, 887 (1996).

[2] A. Adare et al. (PHENIX Collaboration), Phys. Rev. C **78**, 044902 (2008).

[3] L. F. Babichev Nonlinear Dynamics and Applications **13**, 282 (2006).